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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXIII.—*The Bearing of Physiography upon Suess' Theories;** by W. M. Davis.

Contents:—Three conclusions reached by Suess. Observations on the Tian Shan Mountains and on the Steppes north of the Tian Shan. Peneplanation of these regions, followed by uplift of the mountains. The existing Tian Shan ranges are not demonstrably the result of tangential movement toward the south. Other examples of mountains carved in uplifted peneplains. Suess' theory of horsts; the great area of subsidence that it requires. Improbability that horsts have stood still while all the rest of the earth subsided. Horsts are probably the result of local uplifts, while all the rest of the earth remains relatively undisturbed.

The eminent Austrian geologist, Professor Eduard Suess, has emphasized three conclusions of his researches. Uplifts are limited to mountain belts, where tangential pressure has acted to produce a resultant uplifting force; mountain ranges are of unsymmetrical structure, as a result of tangential movement, and not symmetrical as a result of axial uplift; plateau-like masses owe their altitude, not to their own uplift, but to the subsidence of the surrounding lower areas. Although displacements are elaborately discussed, it is notable, as has been pointed out by various students of Suess' works, that he gives only a minimum of attention to the processes and results of erosion, whereby so many features on the face of the earth have been given their actual expression. The present article offers some considerations on this aspect of the subject, and leads to conclusions that differ from those reached by Suess.

As a member of Professor Raphael Pumpelly's Carnegie Institution expedition to Turkestan in 1903, I had opportunity of crossing the western ranges of the Tian Shan mountain system, where the occurrence of a curious flat-topped range,

*Revised, January, 1905, from a paper presented before the Eighth International Geographic Congress in Washington, September, 1904.

the Bural-bas-tau, in the neighborhood of Son-kul (lake), attracted my attention. Its plateau-like surface was heavily snow-covered at an altitude of 12,000 or 13,000 feet or more; its northern flank was deeply gashed with deep ravines heading in glacial cirques; the rocks exposed in the cirque walls and in the sharp arêtes between the ravines seemed to be massive crystallines, but as my observations were made with a field-glass at a distance of ten or fifteen miles, this point will not be insisted upon. Yet in any case there was no indication of horizontal structure, with reference to which the even highland surface might have been determined. I have published a brief account of the range in Appalachia (x, 1904, 277–284). There is no question in my mind that the plateau-like mountain top is a displaced fragment of a peneplain, and hence that its present highland surface is the work of erosion at a comparatively moderate height above baselevel of an earlier time.

Other ranges in the Tian Shan system exhibit similar displaced or tilted blocks of a peneplain, though none of them that I saw are so remarkable in this respect as the Bural-bas-tau, whose highland combines the features of exceptional smoothness, great altitude, and unusually good preservation. The Alexander range, west of Issik-kul, seemed to be a tilted block, with a gentle slope to the south independent of structure, and an abrupt descent to the north. The western end of the Kungei Ala-tau, north of Issik-kul, was of plateau-like form. It is noteworthy that when the even highland of the western part of this range is projected eastward, it seems to rise above the serrate summits of the rest of the range. The same is true regarding the westward prolongation of the highland in the Bural-bas-tau. Both these examples therefore suggest that certain ranges of Alpine form, in which the sharp peaks now give no indication of having been carved from a flat-topped mass, may nevertheless have had precisely such an origin. It is also to be noted that in these cases the relation of the serrate peaks to the even highland is not such as to suggest that the former are recarved residuals that once rose above and more or less completely surrounded the latter. Other examples of ranges that indicate former peneplanation are described in my part of Professor Pumpelly's forthcoming report. All these ranges seemed to be isolated and dissected blocks of a broken peneplain.

Between Viernyi and Semipalatinsk (northeastern Turkestan and southern Siberia), I crossed many miles of rolling steppe of small relief and of moderate altitude above sea-level. Parts of this extended surface came nearer to the realization of a low-lying peneplain than anything that had previously come under my observation, yet even there the surface was prevail-

ingly undulating, so that laterally swinging rivers can have had little share in its production: the only exception to this rule was in the immediate neighborhood of the Irtysh river, whose lateral swinging may have there been effective. The rocks were crystallines or disordered sedimentaries, and the gently undulating surface was evidently the result of long continued subaërial erosion. Here and there mountains rose; some of them seemed to be residual masses, as they had undulating skylines; others seemed as clearly to be isolated blocks of the peneplain, as they possessed uplands of remarkably even form. The conclusion thus grew upon me that the whole region, mountains and steppes alike, had once been greatly worn down, although it probably retained strong monadnocks here and there; and that the mountain ranges which we see to-day had been afterwards uplifted in blocks of greater or less extent; the residual eminences of the former cycle presumably form the loftiest peaks that rise above the present highlands.

This conclusion was strengthened on receiving the report of my companion, Mr. Ellsworth Huntington, who had turned southward from Issik-kul and crossed the Tian Shan to Kashgar. He found large plateau-like highlands of deformed structure and moderate relief surmounted by occasional higher eminences, monadnock-like, and deeply dissected by steep-sided valleys, and he was thus convinced that these highland areas had gained their altitude relative to sea level in comparatively recent time, after prolonged erosion: he describes the Tian Shan, where he crossed it, as "potentially but not actually mountainous." Farther eastward, however, the dominating mass of Tengri-khan is actually mountainous in a high degree: it may be provisionally regarded as a reëlevated surviving mountain group of the former cycle. On looking over the reports of other observers after my return home, several brief descriptions of the plateau-like aspect of the Tian Shan highlands were found; but the only account which interprets their meaning is by Friedrichsen, a pupil of Richthofen's, who visited the region in 1902, and who is now docent in geography at Göttingen: his articles unfortunately came to my notice only after my return from Turkestan. He recognizes the even highland which he saw southeast of Issik-kul to be a formerly lower-lying *Denudationsfläche*, now displaced and exposed to revived erosion, but thinks it may have been worn down with respect to a local baselevel in a relatively enclosed basin (Petermann's Mitteilungen, xlix, 1903, 136), and hesitates to express an opinion as to the area over which correlated peneplains once extended.

In view of these interpretations, it seems inadmissible to follow Mushketof and Suess in regarding the Tian Shan as a

mountain range due to lateral pressure. Its rocks may certainly have suffered compression in some past age, for they not infrequently exhibit deformation of the kind that geologists accept with good reason as evidence of the action of tangential forces. Furthermore, the region may in some past time have risen to mountain heights as a result of such compression, for it seems reasonable to associate superficial disorder and elevation with crustal compression, whether the work of compression be superficial or deep-seated. But the time when compression deformed the rocks and when the region rose in mountain form as a result of such compression must now be long past, because the even surfaces or peneplains of the highlands and the steppes truncates the disordered structures, and thus proves that a long period of erosion—in effect, a physiographic cycle—has elapsed since the compression took place; and to this period must be added the early part of another cycle, sufficient for the dislocation, elevation and partial dissection of the peneplain and its residuals of the first cycle. The ranges that my path crossed were so largely composed of massive crystalline rocks that it is impossible for me to state what relation generally exists between the trend of the existing ranges and the strike of the deformed strata: in one small range, the trend of the crest and the strike of its steep dipping beds diverged at a strong angle; in another case, there was rough coincidence between range trend and strike of slaty cleavage; both these ranges gave good indication of having been worn down to low relief before their present altitude was gained. It is, therefore, not now possible to say what relation exists between the reliefs of the original ranges, due to compression, and the existing ranges, due to some other kind of displacement.

Whether the peneplain fragments seen in the existing ranges and the broad peneplain of the steppes were once parts of a single very extensive peneplain, or whether they represent parts of neighboring but isolated peneplains, need not now be further considered—particularly as the facts needed to settle this question are not yet in hand. It is sufficient to note that the actual attitudes of the peneplain fragments, large and small, now seen in the Tian Shan ranges are not such as to indicate the direct action of forces of horizontal compression. It is true, as above intimated, that one may suppose the dislocation of the mountain blocks to be the superficial result of a deep-seated compression; but our ignorance of the processes that go on within the earth is so profound that a speculation of this kind has no compulsory value; it certainly does not entail the classification of the existing Tian Shan system in the group of mountains due to forces of lateral compression. Hence the Tian Shan should not, in my

opinion, be adduced as an example of "tangential movement directed toward the south" (Suess, Das Antilitz der Erde, i, 603; French translation, i, 619), nor should its topographic arrangement be taken to support the thesis that a certain curvature of ranges and a certain disposition of steeper slopes, noted in various mountain systems and described for the Tian Shan by Mushketof, are either the result of or the index of tangential pressure. The Tian Shan appears to be the result of displacements that have taken place in part of a very extensive degraded region: as a consequence of the displacements, large areas, that were previously below the reach of effective attack by streams, have come to be high above baselevel, so that they are exposed to the most energetic erosion. Having lived nearly through one cycle, they have now entered a second cycle of mountain sculpture; but there is no clear reason for thinking that forces of compression rather than forces of uplift have acted to renew their mountain height.

The case of the Tian Shan is less exceptional than it may appear at first sight. It is now nearly thirty years since Gilbert announced that forces of uplift, perhaps involving horizontal extension, and not forces of horizontal compression, gave the best explanation of the Basin ranges of Utah and Nevada. At a later date, various other ranges in the United States came to be regarded as uplifted masses, with more or less warping or tilting, but without recognizable compression, because their even crest lines or highlands appeared to be the result of peneplanation in an earlier cycle of erosion: the Sierra Nevada in California and the Appalachians in the Atlantic States were among the first to be thus explained; since then, the Cascade and the Coast ranges of Oregon and Washington have been similarly treated, and Gilbert has lately given an account of a lofty and dissected peneplain in the mountains of Alaska. In the meantime, similar results have been reached in Europe. The highland fjelds of Norway are now treated by Reusch and others as having been reduced to moderate relief by long-continued erosion during a lower stand of the land, and afterwards given a greater elevation: there is no indication that their present altitude has been gained by crustal compression. More recently, de Martonne has announced a similar sequence of events for the Carpathians, and Penck has done the same for the Alps. Willis' recent explorations in China led him to similar results regarding extensive mountainous tracks in that far-off country. It was indeed a matter of special interest to the physiographers who attended the International Geographic Congress last autumn to hear the independent testimony of these three observers to the effect that the ranges which they described did not owe their present altitude to forces of compression, however much

their rocks may have been horizontally crushed in some earlier period of deformation; for in all three cases the mountainous areas were described as having been worn down to moderate relief after their rocks had been deformed, and their present altitude was explained as having been gained subsequently, by displacements from which the accepted characteristics of compression were absent. In none of the examples here adduced was particular attention paid by the investigators above named to the features of asymmetry and curvature of mountain tread, upon which Suess lays importance; hence that phase of his theory is not here further considered; but in so far as the present relief of the ranges mentioned is concerned, it should not, if the explanation by non-compressional displacement is correct, be ascribed to or correlated with tangential movement, however fully the internal structure of the ranges may be thus accounted for. My own observations on the Tian Shan had led to essentially the same conclusions, as already stated.

The nature of the forces by which displaced fragments of peneplains have gained their present altitude is not at once apparent, but the following considerations lead to the belief that forces of uplift may have acted in giving such ranges as the Bural-bas-tau and its fellows their actual elevation. If it be agreed that the highlands of the Tian Shan are parts of a once relatively low-lying peneplain, and that their present attitudes exclude lateral compression as a cause of their present altitude, then two contrasted explanations may be offered to account for the crustal displacement by which the rivers of the region have been excited to deep erosion of the surface that was previously safe from their attack. It may be supposed, on the one hand, that the whole region once had the altitude of the Bural-bas-tau highland and its fellows, and that since then the now lower parts of the region have subsided to the present levels; or, on the other hand, that the whole region once had an altitude similar to that of the steppes between Viernyi and Semipalatinsk—with as many and as strong monadnocks and residual ranges as further observation shall demand—and that since then the higher parts of the region have been uplifted. The first supposition is the view adopted by Suess and by a number of European geologists; the second is the view generally accepted by American geologists, as well as by some Europeans. I have not been able to devise any means of making absolute choice between the two views, but it seems to me that many reasons may be adduced for the probable correctness of the second view rather than of the first.

The theory of subsidence may be called the theory of *horsts*; *horst* being a mass of earth-crust which is limited by faults and which stands in relief with respect to its surroundings. The Harz mountains in northern Germany and the central plateau

of France may be mentioned as smaller and larger examples in Europe; the plateaus of northern Arizona are examples in this country. *Graben* are the reverse of horsts, being fault-bounded areas that stand below their surroundings. The valley of the middle Rhine is a famous European example: the troughs of certain of the great African lakes, described by Gregory as "rift-valleys," are also *graben*. According to Suess' analysis of the problem, the movements which produce horsts and graben "are easily explained, in the absence of tangential movements, by a yielding of the support and by the force of gravity. Everything of this kind that one observes is only a variation on passive settling or sinking" (Das Antlitz der Erde, i, 165; French translation, i, 162). "Great plains may sink down; as soon as their support yields, they obey the action of gravity; but we know no force capable of uplifting, unequally and locally, mountainous masses situated side by side" (ibid., i, 736; i, 775). He continues, there are two facts which we cannot escape: the first is that "large areas have simply sunk down under the influence of gravity. The second is that no force is known capable of uplifting numerous great and small mountainous masses vertically and independently, between two plane surfaces, and of sustaining them in this uplifted position permanently, in spite of gravity" (ibid., i, 741; i, 782).

With all the respect that one must feel for the erudition of such a master of the geology of the whole earth as Suess has shown himself to be, the conclusions indicated in the above extracts do not seem to me to be proved. The faults by which horsts and graben are bounded truly show a differential movement, more or less nearly vertical, but the means of determining, independently of all theory, which mass went up or which mass went down are, to say the least, obscure. The observed facts of dislocation taken alone are consistent with various suppositions as to the movement of the adjoining masses: both may have moved upwards, one more than the other; both may have moved downwards, one more than the other; one may have stood still, and the other may have moved; both may have moved, one upward, the other downward. It is not satisfactory to appeal to our ignorance of available forces of uplift and support as a mean of choosing among these alternatives: the operations of the earth's interior are so little understood that we are as much in the dark about their action as they are. Nor does the accumulation of examples that may be explained by subsidence strengthen the case, unless it is shown at the same time that they cannot be explained by upheaval. The actual movement of faulted masses can be rigorously determined only by relating them to some fixed standard of comparison, and that is no easy task. It seems hopeless in the present state of our knowledge to speak of movements with respect to the earth's center; for the sea-surface and not the earth's center is our

only standard of comparison. It is at best a movable standard, yet in the present problem it will fairly serve our purpose.

So far as I have been able to learn, the horsts described by Suess are not examined to discover how far the form of their surface may give indication of the altitude that they possessed with respect to sea-level before the occurrence of the faults by which they have been placed in relief: yet such an examination is well worth while. In the case of the Schiefergebirge of the middle Rhine, for example, the form of the upland is for the most part that of a well-developed peneplain, more or less warped, here and there surmounted by residual monadnocks, and now dissected by valleys. This district, therefore, stood at a moderate altitude above sea-level, before its present altitude was gained. Hence, if the present altitude were gained by the subsidence of the surrounding lower lands, we are constrained to believe that not only the surrounding lower lands, but all the oceans went down as well, and all the continents with them—the Schiefergebirge and the neighboring uplands alone standing still. The same is true of the plateau of northern Arizona, across which the Colorado has cut its precocious canyon: the plateau is a surface of denudation, and according to the most reasonable interpretation was once a lowland of small height above sea-level: if its present altitude has been passively gained by the subsidence of the surrounding lower districts, then in this case again all the oceans must also have gone down, and the rest of America aud the other continents with them. Many more examples of the same kind might be mentioned, but the most impressive one that has come under my own observation is the Bural-bas-tau. It seems extravagant to suppose that all the rest of the lands and seas had to sink by some 10,000 feet in order to leave that range and its fellows in strong relief.

It is not intended, however, to imply that every horst was formed by a separate subsidence of all the rest of the world, for in so far as peneplained horsts are of the same date of production and of the same altitude, one subsidence of the rest of the world will suffice for their production; but many of the known examples of such horsts are in very different stages of dissection, and they stand at different altitudes; hence various widespread subsidences must, according to this theory, be admitted in order to account for them. It is not clear to me whether this world-wide extension of subsidence has been considered by Suess: it does not seem to be explicitly excluded in his writings; it may be that it is tacitly accepted, to be more fully treated in later volumes: he says indeed, in discussing changes of level in the Rocky mountains, "we shall have to return to questions of this kind, and I hope then to be able to show that there is need of correcting more than one wide-

spread opinion concerning the position of sea-level in epochs anterior to ours" (ibid., i, 740; i, 782). For my own part, I know of no complete disproof of the theory of subsidence, enormous as its demands appear to be. It is in a certain sense conceivable that the Bural-bas-tau stood still, like a post in a frozen pond, while all the rest of the world went down two miles, like the sinking ice when the pond water is drawn off—this being an analogy suggested by Suess himself (ibid., i, 736; i, 774); nevertheless, in the absence of definite knowledge as to the mechanics of the earth's interior, it seems legitimate to entertain some more economical alternative hypothesis whereby the Bural-bas-tau and its fellows were locally uplifted about two miles from their former lowly estate, as a result of relatively local deep-seated movements of the earth's under mass, about which the great body of the earth knew little. How these deep-seated movements may be caused, it is impossible now to say. Two methods of search may lead to the discovery of their origin and character: one method proceeds partly from general facts as to the density, temperature and composition of the earth, and partly from general speculations as to cosmical history and the evolution of the earth; the other proceeds from special facts as to the deformations that the earth's surface has suffered, with abundant detail as to time and place. In briefer phrase, one method seeks to determine the character of the earth's internal movements from their causes; the other, from their effects. It will probably be long before either or both methods reach a solution of so recondite a problem. In the meantime, it seems advisable to take the sea-level as our standard of reference, and to speak of now high-standing isolated peneplains as locally uplifted, all the rest of the world remaining relatively undisturbed, whether the forces that produce the uplift are explained or not.

Similarly, a graben may be spoken of as a sunken area, when there is evidence that its position with respect to sea level had been lowered, as would appear to have been the case with the floor on which the Triassic beds of Massachusetts and Connecticut were deposited; but in such examples as the Rhine graben it does not seem legitimate to measure the amount of sinking from the level of the high-standing peneplains in the highlands on the east and west.

In all these cases of local change the sea surface may be provisionally regarded as fixed. A change in the level of the sea must be universal, synchronous and of equal amount (except for concomitant local changes in a land mass) along all shore lines. A universal change should be accepted only when demanded by widespread and accordant evidence, such as Suess has in so masterful a manner brought forward in the case of the world-wide Cretaceous transgression.

ART. XXIV.—*On the Progress of the Albatross Expedition to the Eastern Pacific;* by ALEXANDER AGASSIZ.

[Extract from a letter to Hon. George M. Bowers, U. S. Fish Commissioner, dated Chatham Island, Jan. 6, 1905.]

WE left Callao for Easter Island Saturday afternoon, December 3; as far as 90° west longitude we remained in the Humboldt current, as we could readily see from the character of the temperature serials and from the amount of pelagic life we obtained from both the surface and the intermediate hauls. This current also affected the bottom fauna, which was fairly rich even as far as 800 miles from the shore while we remained within the limits of the northern current. As soon as we ran outside of this the character of the surface fauna changed; it became less and less abundant as we made our way to Easter Island, the western half of the line from Callao becoming gradually barren. This current also affected the deep-sea fauna to such an extent that towards Easter Island, at a distance of 1,200 to 1,400 miles from the South American continent, our trawl hauls were absolutely barren; the bottom of the greater part of the line was covered with manganese nodules on which were found attached a few insignificant siliceous sponges, an occasional ophiuran, and a few brachiopods or diminutive worm tubes, the same bottom continuing to Sala y Gomez and between there and Easter Island. Sala y Gomez and Easter Island are connected by a ridge on which we found 1,142 fathoms near Sala y Gomez, and 1,696 fathoms between that point and Easter Island. The ridge rises rapidly from about 2,000 fathoms, the general oceanic depth within about 100 miles, to over 1,100 fathoms within a comparatively short distance from both Sala y Gomez and Easter Island.

The southern part of our line from Easter Island to the Galapagos shows all the features characteristic of the western part of the line from Callao to Easter Island; like the latter, as far as the 12th degree of southern latitude it proved comparatively barren, the bottom consisting of manganese nodules to within about 250 miles of the Galapagos. The pelagic and intermediate fauna from Easter Island to 12° south latitude was very poor, and the serial temperatures show that we were outside and to the westward of the great Humboldt current. But near the 12th degree of southern latitude a sudden change took place; the pelagic and intermediate fauna became quite abundant again and soon fully as rich as at any time in the Humboldt current. There was also a marked change in the temperature of the water as indicated by the serials, showing that from the 12th degree of southern latitude to the Galapagos we were cutting across the western part of the Humboldt

current. The great changes of temperature which took place in the layers of the water between 50 and 300 fathoms are most striking, and show what a disturbing element the great mass of cold water flowing north must be in the equatorial regions of the Panamic district to the south and to the north of the Galapagos. South of the Galapagos the western flow of the Humboldt current must be nearly 900 miles wide, and of about the same width when running parallel to the South American coast.

The range of temperatures between 30 fathoms and 150 fathoms is at some points as great as 21°. Such extremes cannot fail to affect the distribution of the pelagic fauna, and may account for the mass of dead material often collected in the intermediate tows at depths of less than 300 fathoms, when the range becomes as great as 28°. Such a range of temperature is far greater than that of the isocrymic lines which separate coast faunal divisions. The bottom fauna, as we entered the Humboldt current going north, gradually became richer in spite of its being covered with manganese nodules.

The two lines centering at Easter Island developed the Albatross Plateau indicated on the Challenger bathymetrical charts, on the strength of a few soundings reaching from Callao in a northwesterly direction and of a couple of soundings on the 20th degree of latitude. The Albatross Plateau is marked as a broad ridge separating the Buchan Basin from the deep basin to the westward, of which Grey Deep and the Moser Basin are the most noted areas.

Our line from Easter Island to the Galapagos showed a wonderfully level ridge, varying in depth only from 2,020 to 2,265 fathoms in a distance of nearly 2,000 miles. The soundings we made to the eastward from the Galapagos to the South American coast, and to the westward of Callao, as well as on the line from Callao to Easter Island, all indicate a gradual deepening to the eastward to form what the Challenger has called the Buchan Basin with the greatest depths of 2,400 to over 2,700 fathoms and passing at several points near the coast to Milne-Edwards Deep, Haeckel Deep, Krümmel Deep, and Richards Deep, some of them with a depth of over 4,000 fathoms. According to the Challenger soundings the Juan Fernandez Plateau connects with the Albatross Plateau and forms the southern limit separating Buchan Basin from the Barker Basin to the south of the Juan Fernandez Plateau.

At Easter Island we found our collier awaiting our arrival. We moved from Cook Bay to La Pérouse Bay to coal, as there was less swell there than in Cook Bay, where we could scarcely have gone alongside for this purpose.

Considerable shore collecting was done at Easter Island. We must have brought together at least 30 species of plants. The flora of Easter Island is very poor. There are no trees

nor native bushes—not even the bushes which characterize the shore tracts of the most isolated coral reefs of the Pacific are found there; and yet some of the equatorial counter-currents must occasionally bring some flotsam to its shores. We collected a number of shore fishes and made a small collection of the littoral fauna. The fishes have a decided Pacific look, and the few species of sea-urchins we came across are species having a wide distribution in the Pacific.

While coaling, we spent some time examining the prehistoric monuments which line the shores of Easter Island. During our stay at La Pérouse Bay we visited the platforms studding the coast of the bay, and made an excursion to the crater of Rana Roraka, where are situated the great quarries from which are cut the colossal images now scattered all over the island, many of which have fallen near the platforms upon which they were erected. Near Rana Roraka, at Tongariki, is the largest platform on the island, about 450 feet in length, to the rear of which are 15 huge images which have fallen from the pedestals upon which they once stood. The plain in the rear of the platform is crowded with stone houses, most of which are in ruins.

On our return to our anchorage at Cook Bay, we examined the platforms within easy reach of the settlement, and also the crater of Rana Kao, on the north rim of which, at Orongo, are a number of the stone houses built by the people who quarried the great stone images. At Orongo are also found sculptured rocks, but neither the sculptures nor the images show any artistic qualities, though the fitting of some of the cyclopean stones used in building the faces of the platforms indicates excellent and careful workmanship. To Mr. C. Cooper, manager of the Easter Island Company, we are indebted for assistance while visiting the points of interest of the island. He was indefatigable in his exertions in our behalf.

We took a number of photographs during our stay, illustrating not only the prehistoric remains, but giving also an idea of the desolate aspect of Easter Island during the dry season.

We arrived at Wreck Bay, Chatham Island, Galapagos, on the 3d of January, where we found a schooner with a supply of coal. As soon as the ship has been overhauled and coaled we shall start for Manga Reva, where we ought to arrive the last days of January. We reached Chatham Island towards the end of the dry season. Everything is dried up; the vegetation seems dead with the exception of a few small wild cotton plants, weeds, cactus, and an occasional mimosa; and the great barren slopes present fully as uninviting an aspect as when Darwin described them. When the Albatross visited the Galapagos in March, 1891, everything was green, presenting a very marked contrast to its present desolate appearance.

ART. XXV.—*Replacement of Quartz by Pyrite and Corrosion of Quartz Pebbles;* by C. H. SMYTH, JR. (With Plate II.)

I. *Replacement of Quartz by Pyrite.*

THE lowest beds of the Oneida conglomerate, in Central New York, are characterized by the presence of considerable pyrite, serving as a cement to bind together the quartz grains and pebbles of which the rock is mainly composed. The relations between the two minerals are worthy of note.

The quartz is, of course, clastic, while the pyrite has been deposited from solution, and would naturally be expected simply to fill the interstices between the more or less perfectly rounded grains of the former mineral, as is the case with the secondary quartz cement of the upper beds of conglomerate.

The pyrite, however, behaves quite differently. Instead of being molded upon the quartz grains and taking its shape from them, the reverse relation holds good, and the form of the pyrite is deeply impressed upon the quartz grains, giving them angular, jagged and pitted contours, totally unlike their original clastic forms. That these contours are secondary and conditioned by the pyrite, admits of no doubt; for not only is the shape of the grains wholly incompatible with water transportation, but, when sections are examined in detail, it is evident that the outlines of the quartz grains are commonly determined by crystal faces of the pyrite, the latter mineral occurring with its own forms, pyritohedron and cube, to which the older quartz has been forced to accommodate itself. In other words, the surfaces of the quartz are such as would have resulted had it been deposited from solution upon the already crystallized pyrite, which is just the reverse of the actual relation. The pyrite seems to have crystallized as readily as though filling open spaces or pushing aside some soft medium, like clay, instead of forcing its way into so refractory a substance as quartz; and, in consequence, the quartz grains are bounded, not by their normal, water-worn surfaces, but by variously oriented minute planes, conforming to the crystal faces of pyrite. Between such grains and those showing their original contour there is a complete gradation, and some of the latter are surrounded by pyrite. But this is decidedly exceptional, the pyrite nearly always eating its way to a greater or less distance into the quartz, while in the absence of pyrite the quartz retains its original form.

Some idea of these various features may be gathered from the accompanying photomicrographs (Plate II). Although

affording a very unsatisfactory substitute for actual sections under the microscope, they suffice to show that the relation between the two minerals is quite different from that ordinarily subsisting between clastic quartz grains and their cement, and can be explained only as resulting from the simultaneous solution of quartz and deposition of pyrite, or, in other words, the metasomatic replacement of quartz by pyrite.

The amount of replacement varies considerably, even within the limits of an ordinary thin section, and sometimes a grain of quartz is considerably replaced on one side, showing the jagged contour impressed by the pyrite, while the other side retains the clearly defined original outline. Figures 1, 5 and 6 (Plate II) show cases of this kind, where the replacement is in early stages and the grains retain their original outlines to some extent, although the pyrite has eaten into them considerably. In figures 2 and 4, on the other hand, few traces of the original margins of the grains are left.

Thus far, in spite of the variation in the amount of replacement, no section has been seen which contains pyrite and does not show replacement. Even where there are but a few scattered crystals of pyrite, they have eaten into the adjacent quartz just as in parts of the rock that are strongly pyritiferous (fig. 1). Sometimes such isolated crystals, and even larger masses of pyrite occur entirely within quartz grains, having, doubtless, been deposited from solutions entering cracks. It is evident, however, that, as a rule, the replacement started at the surfaces of the grains.

This is a matter of interest in its bearing upon the history of the replacement, as it shows plainly that the solutions effecting the change circulated through the beds of sand and gravel before they were cemented. For, had these beds been indurated, as the upper beds are now, by secondary quartz, filling the interstices between the grains, any replacement that might have followed would have been controlled by secondary surfaces, resulting from fractures subsequent to cementation, and would show no such dependence upon the original surfaces of the quartz grains.

Such openings as escaped complete filling by pyrite were subsequently closed by secondary quartz. It is evident that when this happened the quartz would take the form of the pyrite, and thus give a texture identical in appearance with that described above. This relation is shown in figures 3, 5 and 6, and may be seen frequently in the sections, but it is always a minor feature; and while, in photographs with low powers, it might be confused with replacement, when seen under the microscope, the results of the two processes are easily distinguished, as they are in figures 5 and 6. There might be some

doubt in the case of very small grains, but with reference to the general relation of quartz and pyrite in the rock, secondary quartz is an entirely negligible factor.

As to the relative amounts of interstitial filling and of replacement, the evidence is quite clear. In the non-pyritiferous rock, the quartz grains are very closely packed and the interstitial filling correspondingly slight, but in the pyritiferous beds the quantity of pyrite between the grains is often considerable. The amount of replacement is greater or less according as the original interstitial space was large or small. While sometimes well-rounded grains are widely separated by pyrite, much the commoner case is the occurrence of jagged contours, and when parts of the original surfaces remain, it is evident that their complete restoration would largely take up the space now filled by pyrite (figs. 5 and 6).

This is repeated so often that it is deemed excellent evidence for believing that the original sand was closely packed, like that of the overlying beds, with small interstitial cavities, and that the considerable space now occupied by pyrite is due chiefly to replacement. According to this view, figures 2, 3 and 4 represent later stages in a process whose earlier stages are represented by figures 1 and 5.

If the space now filled by pyrite were regarded as original, it might be concluded, as there is no reason for assuming the former presence of any other cement, that the sand and pyrite were deposited simultaneously, the pyrite coating the grains and thus keeping them from being closely packed. Primary deposition of pyrite in sediments is common, an instance described by Reusch* being of particular interest in this connection; and this explanation is favored by the apparently fixed stratigraphic position of the pyrite, and the fact that it was deposited before the secondary quartz. But if the foregoing interpretation of the texture of the rock is correct, a later introduction of the pyrite is indicated; although, so far as the evidence goes, it may have followed closely upon the deposition of the sand and gravel, while they were still exposed upon the sea bottom. This latter view, which is but a slight modification of the preceding, would account equally well for the position of the pyrite and for its deposition before the secondary quartz.

While it is a general rule that the primary pyrite of sediments is deposited in the presence of abundant organic matter, which is lacking in the conglomerate, the underlying Lorraine formation would be a possible source of hydrogen sulphide and other reducing agents.

* Neues Jahrbuch f. Mineralogie, etc., 1879, p. 255.

Thus, so far as the pyrite itself is concerned, there is reason for thinking that it was deposited in the gravel and sand lying uncovered on the sea bottom. But, on the other hand, it is difficult to believe that, had the pyrite been so deposited, there would have been any replacement of quartz. Such metasomatic processes usually take place after rocks are deeply buried, and subjected to the action of underground waters; and while, in the case of a readily soluble mineral, such as calcite, sedimentation and replacement are often practically simultaneous, with our present limited knowledge of the chemical reactions on the sea bottom, it seems unlikely, in spite of the evidence given later as to the solubility of quartz under surface conditions, that this would be true of quartz. Thus, it appears probable that the replacement of quartz by pyrite was effected by ground waters, rather than by chemical reactions coincident with, or directly following, the deposition of the sand and gravel. But as this conclusion is based upon general considerations rather than upon direct and positive evidence, it may be modified by future investigation.

As to the bearing of the stratigraphic position of the pyrite upon the above conclusions, it should be said that, owing to the unsatisfactory exposures of the formation, there is much to be learned with reference to the precise distribution of the pyrite, and it is certain that the higher beds often contain enough of the mineral to weather yellow, brown and black. It seems, therefore, unwise to lay great stress upon the stratigraphic position until it is more accurately determined.

However, even if the pyrite is largely confined to a definite horizon, at the bottom of the conglomerate, it is possible to reconcile the fact with the above conclusion as to its secondary origin. Before cementation, the conglomerate must have been a permeable formation, permitting a free circulation of water. Immediately beneath it, on the other hand, the fine-grained Lorraine formation would be relatively impervious, and thus, along the contact, or in the bottom beds of the conglomerate, the conditions would be favorable for deposition. These beds might be quite uniformly impregnated with such a mineral as pyrite, which, in consequence, would have a definite stratigraphic position, in spite of its secondary origin.

With so much that is uncertain, it is not worth while to make any attempt to explain in detail the chemistry of the deposition of pyrite and replacement of quartz, but it is natural to suppose that hydrogen sulphide and iron and alkaline carbonates were active agents in the process. These compounds are sufficiently common in ground-waters to warrant the assumption of their former presence where effects are observed of which they would be a probable cause, although there are

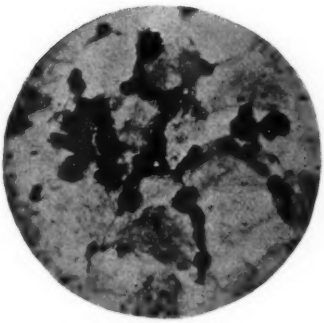


Fig. 1, × 26 diam.

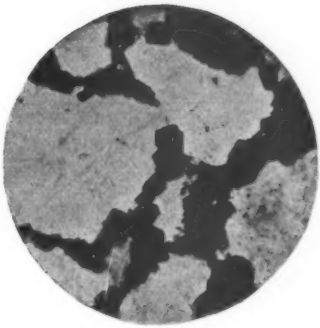


Fig. 2, × 26 diam.

Fig. 3, × 26 diam.

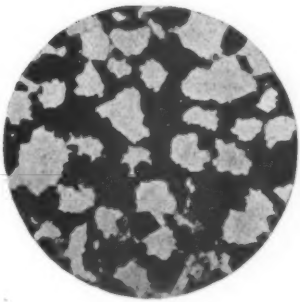


Fig. 4, × 23 diam.

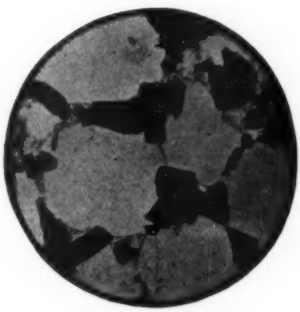


Fig. 5, × 67 diam.

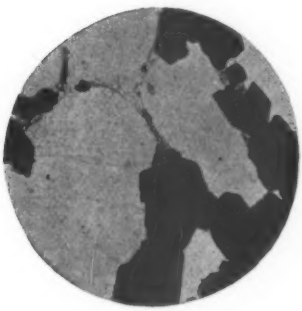


Fig. 6, × 67 diam.

difficulties as regards concentration. In the present case, while there is no obvious source for any unusual quantity of alkaline carbonates, a sufficient supply might, perhaps, be furnished by overlying shales, while the Lorraine formation might be a source of hydrogen sulphide. Iron may have been original in the conglomerate, or derived from overlying rocks. In this connection, Doelter's* production of artificial pyrite by the action of hydrogen sulphide and sodium sulphide on iron carbonate is very suggestive, and may represent some approximation to the conditions involved in the case under consideration.†

If this is true, it is evident that the replacement of quartz by pyrite is caused by common, rather than peculiar, agents, and therefore might be expected to occur with some frequency. As a matter of fact, judging from the literature of ore deposits, it is by no means rare. Lindgren‡ in particular has described several instances within very recent years.

But in all the cases that the writer has thus far found mentioned, the process is connected with some type of mineral vein formation, where, with the hot alkaline solutions and mineralizers, and resultant powerful chemical action, it is not surprising to find even so resistant a mineral as quartz yielding to the agents of alteration. In some of these cases it is, as in the present instance, the quartz of sedimentary rocks that is replaced, but always under the conditions involved in the filling of mineral veins.

These conditions are so unlike those controlling the deposition and subsequent existence of the Oneida conglomerate that the occurrence of pyrite replacing quartz in veins would hardly suggest the probability of the same thing taking place in the conglomerate, and explanations of the former process would, doubtless, require modification before being applied to the latter.

The reagents suggested above are similar to those filling veins, but in the case of the conglomerate their action would, probably, be less intense, owing to lower temperatures and pressures, greater dilution, and the absence of some of the more powerful reagents. Compensation might be afforded by the ready permeability of the formation and the large surface of quartz exposed to attack, while, of course, the time factor

* Allgemeine Chemische Mineralogie, p. 148.

† See a theoretical discussion of the chemistry of pyrite-quartz replacement by C. S. Palmer, Eng. and Min. Jour., lxxix, p. 169.

‡ Metasomatic Processes in Fissure Veins, Trans. Am. Inst. Min. Eng., xxx, p. 615, et seq.

Gold and Silver Veins in Idaho, 20th Ann. Report, U. S. Geol. Survey, iii, p. 219 et seq.

Geological Reconnaissance across the Bitterroot Range, etc. U. S. Geol. Survey, Professional Paper No. 27, pp. 109–110.

would be most important in determining the amount of replacement.

How frequently all the conditions necessary for the replacement of quartz by pyrite are fulfilled in formations similar to the Oneida conglomerate, it is at present impossible to say. Judging from the literature, the matter has never been investigated, which doubtless explains the fact that, so far as the writer can learn, no case similar to the present one has been described.

Whatever sheds light upon the geological relations of so important a mineral as quartz is worth recording, but it is evident that this case of the replacement of quartz by pyrite is of particular significance in its bearing upon ore deposits. In the present instance, the total amount of replacement is comparatively small, but there seems to be no reason why, under more favorable conditions, there should not be a more extensive, or even complete, replacement of quartz by pyrite, and, perhaps, by other sulphides. Although this may be going too far, it is, at least, evident that the phenomena described suggest interesting possibilities.

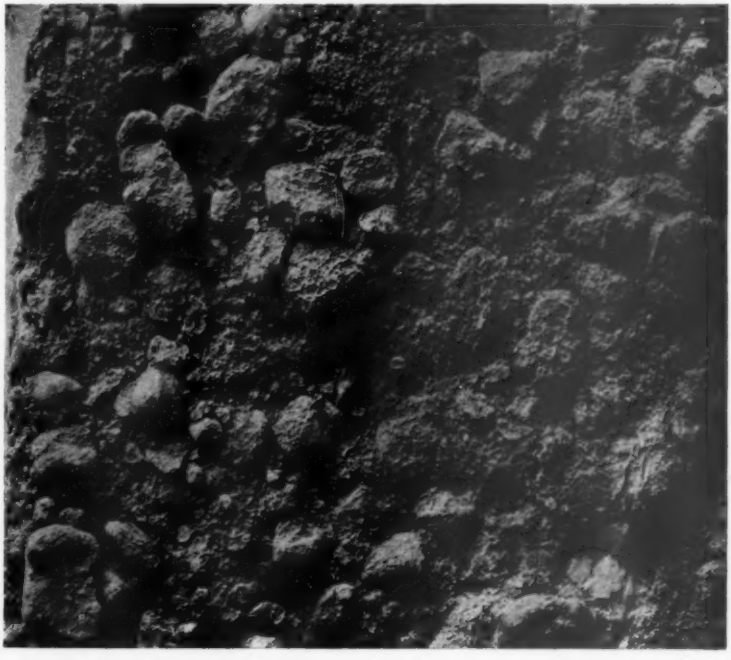
II. *Corrosion of Quartz Pebbles.*

While the replacement of the quartz is clearly a process which was accomplished early in the history of the conglomerate, the same mineral occasionally shows evidence of another change, going on under very different conditions at the present time. Several specimens have been found with projecting pebbles of quartz deeply corroded in a manner indicating the action of some solvent, working, not throughout the mass of the rock, but upon surfaces of bedding planes, or, rarely, of joints and boulders—in other words, where there is exposure to weathering conditions.

The pebbles show most irregular surfaces, often pitted, with sharp jagged projections, and in extreme cases, appear to have lost a considerable fraction of the original mass. As a rule, solution has been most rapid on the tops of the pebbles, and as the cement and sand work out beneath, there is also rapid solution here, the result being the reduction of pebbles to thin plates, with very jagged edges and rough surfaces. Such a marked effect is, however, exceptional, the pebbles more commonly showing a less pronounced change of form, but having the characteristic etched surfaces. The accompanying illustration from a photograph (fig. 1), showing a portion of the surface of a typical specimen (natural size), gives a fairly clear representation of corroded pebbles. While the sand grains are similarly affected, the phenomena are, naturally, much less easily observed.

Unlike the replacement by pyrite, this corrosion of the quartz seems to be a rather exceptional feature of the rock, as but few good examples have been found.

The character of the corroded pebbles is essentially the same as that described by Hayes* and by Fuller,† but in both of these latter cases the pebbles appear to have suffered greater loss, while there is a stronger tendency towards a rapid solu-



tion of the center of the pebble, leaving the margin as a projecting rim. This form is seldom even approximated in the Oneida specimens, but the resemblance to wind-facetted pebbles, noted by Hayes, is sometimes quite pronounced.

Hayes explains the corrosion as due to the action of the azo-humic acids of decaying organic matter, combined with potash derived from forest fires, and regards the process as taking place at the surface.

Fuller concludes that the quartz is dissolved by organic acids supplied by plants buried in the rock when it was deposited,

* Bull. Geol. Soc. Am., viii, pp. 213–226.
† Jour. Geol., x, pp. 815–821.

and holds that the process has taken place at moderate depth beneath the surface.

Long ago, Newberry* regarded the impressions of plant stems upon the quartz pebbles of conglomerate as due to organic acids, and, as quoted by Bolton,† explained in the same way the corrosion of quartz pebbles occurring in carbonaceous clay.

As the present instances of corrosion show no connection with unusual supplies of decomposing organic matter and alkalies, at the surface; and as the conglomerate contains little, if any, original organic matter, none of these explanations seems applicable; but, unfortunately, no satisfactory substitute is forthcoming.

As already stated, the corrosion appears to be a superficial process—a peculiar phase of weathering. To this may be added the striking fact that, thus far, corroded pebbles have been found only in the pyritiferous beds, though carefully sought for in the overlying pure quartz conglomerate.

Thus, corrosion seems to be dependent upon two conditions, —presence of pyrite and weathering,—which suggests the conclusion that the products of the weathering of pyrite act as solvents of quartz. But, so far as the writer is aware, such a conclusion finds no support in the results of laboratory study; and an explanation of the phenomena must await further investigation.

It might be suggested that the corrosion is merely apparent, not real, resulting from the weathering out of pyrite from partly replaced quartz, thus leaving, as would evidently be the case, a rough pitted surface. This simple explanation is not, however, in harmony with the facts. The replacement though greatly modifying the shape of small sand grains, perhaps even completely destroying them in some cases, does not go deep enough to materially change the shape of the larger pebbles, upon which corrosion is conspicuous. So, while mere weathering out of pyrite would give a rough surface, it would not yield the deeply corroded pebbles. Furthermore, a surface left by the removal of pyrite would be marked by depressions corresponding in shape with the pyrite, and, thus, often bounded by small plane faces, which is distinctly not the case with the corroded pebbles.

The rough surface left by the removal of pyrite would, of course, favor solution of the quartz by any agent present, and to this extent, surely, replacement is a factor in the subsequent corrosion.

The Oneida conglomerate, then, presents two types of solu-

* Geol. of Ohio, vol. ii, pt. I, p. 111.
† Ann. N. Y. Acad. Sci., i, 1877, pp. 35-36.

tion of quartz, one accompanied by simultaneous replacement by pyrite, and thus metasomatic, the other purely destructive in its nature, and in harmony with the general tendency of weathering. While neither of these processes is of great moment in the history of the formation as a whole, they are interesting in that, as they seem to represent no very unusual conditions, they suggest the possibility that quartz, though unquestionably an exceedingly resistant mineral, may yield rather more readily to the attack of natural solvents than has generally been supposed.

Hamilton College, Clinton, N. Y.

Description of Plate II.

Figure 1.—Early stage of replacement, with crystals and irregular masses of pyrite growing between, and into, the quartz grains. Magnified 26 diameters.

Figure 2.—Original margins of quartz grains almost entirely removed, giving jagged contours determined by the forms of pyrite. Magnified 26 diameters.

Figure 3.—Pyrite with unusually irregular forms. Some secondary quartz in upper half of section. Magnified 26 diameters.

Figure 4.—A typical example of replacement in a fine-grained specimen. Nearly all the quartz grains are affected, and show the characteristic contours resulting. It is quite possible that some small grains have entirely disappeared. Magnified 23 diameters.

Figure 5.—Pyrite filling interstitial spaces, and projecting slightly into quartz grains, whose original margins are partly preserved. Some secondary quartz. Magnified 67 diameters.

Figure 6.—Shows very clearly the contrast between original and secondary contours of quartz grains, together with the dependance of the latter upon the forms of pyrite. Some secondary quartz. Magnified 67 diameters.

ART. XXVI.—*Occurrence and Distribution of Celestite-Bearing Rocks;** by EDWARD H. KRAUS.

IN July, 1904,† I announced the fact that the mineral celestite occurs quite extensively in a disseminated condition in the dolomitic limestones and shales in the upper portion of the Salina epoch. The celestite-bearing rocks studied at that time were confined to localities in Central New York, especially those near Syracuse. However, in describing the various occurrences, the following statement was made: "I do not doubt, whatever, but that its (celestite) occurrence in the disseminated condition, as shown by the accompanying figures, is just as extensive in the limestones of the Salina elsewhere, as in the vicinity of Syracuse."‡

During the past summer, the Island of Put-in-Bay in Lake Erie was visited. This island has become well known for its interesting caves, among which is the celestite cave, popularly known as "Crystal" or "Strontium" cave. The rocks of the island have been assigned to the Lower Helderberg epoch. Wherever they are exposed along the lake shore they present a more or less porous appearance. There are a goodly number of exposures in various places on the island away from the shore, and even in such places many of the rocks have a structure which is so characteristic of the leached celestite-bearing rocks of Central New York. Numerous specimens were found lying on the surface, which possess cavities with a distinct orthorhombic outline. A very careful search failed to reveal celestite in the interior of such rocks, but the outline of the cavities leaves no doubt, whatever, as to the mineral which had previously occupied them. There is a very striking similarity between these rocks from Put-in-Bay and those from various localities near Syracuse, N. Y. In some instances it would be difficult to tell which specimens were from either place, were it not for the fact that those from Put-in-Bay are for the most part a little lighter in color.

The dissemination of the celestite in the rocks near the surface in the Put-in-Bay region was principally, so far as I have been able to ascertain, in the form of small but well-defined crystals. Celestite has been known to occur for many years at this locality, and also on some of the other islands in the southwestern portion of Lake Erie. Nearly all text-books on mineralogy mention these islands as important localities for

* Read in part before the Philadelphia meeting of the Geological Society of America, December 30, 1904.

† This Journal (4), xviii, 30–39, 1904.

‡ Ibid. (4), xviii, 33, 1904.

the mineral. The celestite, however, which has been studied up to the present time has, in so far as my knowledge goes, all been of secondary origin, in that it has always been found in the cracks, crevices, or cavities in the rocks.

The discovery of the "Strontium" or "Crystal" cave in 1897 showed conclusively that there must have existed somewhere on the island a very large amount of celestite. This cave is perhaps 25 to 30 feet in its extreme dimensions. The form is somewhat irregular and the interior is lined on all sides with well-developed crystals of celestite, some of which are eighteen inches in length. In opening this cave to the public it was necessary to remove some of these crystals in order that suitable passageways might be made. The owner, Mr. Gustave Heinemann, estimates that in so doing no less than 150 tons of celestite were removed. This, however, represents but a small portion of what still remains.

G. F. Wright,* in describing this cave, speaks of it as an immense geode. There is no doubt, whatever, of the secondary origin of the celestite. An examination of the rocks immediately overlying the cave shows that they are of a more or less porous nature.

At the time of my visit to the island in August, 1904, several wells had just been drilled—one on the farm of Louis Schiele on the southeast shore of the lake, and the other at the hotel of August Markley on the road extending southward from the main dock. This last well is not over a quarter of a mile from the "Strontium" cave. Many cores were obtained from these wells. These cores show that the rocks near the surface are very porous. In many instances the cavities are well preserved and reveal the celestite outline. The rocks near the surface show small cavities, but as we go deeper the cavities become much larger, some over an inch in diameter, and the rocks are crossed by numerous cracks. It is in these larger cavities and cracks that excellent crystallizations of celestite are found. These lower cavities, however, do not possess a definite outline, but are more or less irregular. The crystals do not in all cases completely fill the cavity, and in no case does the cavity conform to the celestite outline, as is the case when the mineral occurs disseminated. Figure 1 shows a core from the Schiele well. This core is from the strata near the surface, and shows clearly the porous condition of the rocks. It is not possible for me to give exact figures as to the depth at which this core was obtained, nor can I state how far below the surface celestite is first encountered filling the larger cavities and cracks, for no detailed record of either this or the

* Science, viii, 502, 1898.

Markley well was kept by the driller, Mr. W. T. Hills. This much, however, can be stated, that the cores from the upper strata show that celestite was present in a disseminated condition, and thus the observations on the surface rocks, which were referred to above, are confirmed. Since this is the case, it can be readily seen that these leached rocks are no doubt the source of the large amounts of celestite which are to be found in some of the lower strata. In this way the very large deposit of celestite, which is to be found in the "Crystal" cave, may be readily explained.

1

In the paper* already referred to, it was shown that the porous character of celestite-bearing rocks is due to the solution of the celestite, brought about by the action of the circulating waters, and figures are given showing that if sodium chloride or the chloride of calcium or magnesium be present in the water, the same becomes an excellent solvent for celestite.† Virick‡ says, that one part of celestite is soluble in but 457 parts of water containing 15 per cent. of sodium chloride in solution. Hopper casts were found in several places on the island, so that, without a doubt, conditions for obtaining a suitable solvent for celestite are also present in the Put-in-Bay region as well as in Central New York.

There is, however, another point concerning the solubility of celestite which is worthy of consideration. It is sometimes supposed that, because celestite resists to a very large extent the action of the common acids, it is insoluble or only very slightly soluble in water. A few figures will suffice to show that such a view is erroneous. According to Fresenius,§ one part of the celestite is soluble in 6,895 parts of cold water. F. Kohlrausch and F. Rose‖ found the solubility of celestite to be one part in 10,101 parts of water at 15° C. Hollemann¶ also obtained figures almost identical with these,

* This Journal (4), xviii, 36, 1904.

† Since the publication of said paper expressing the belief that the Vermicular limestones of Central New York owe their origin to the removal of celestite—once disseminated throughout them—by percolating waters containing sodium chloride in solution, I have found that in 1869 Bauermann and Foster (Phil. Mag., 38, 1862) had expressed similar ideas concerning the solution of celestite in nature.

‡ Chemisches Centralblatt, 1862, 402; Comey, Dictionary of Chemical Solubilities, 1895, 455.

§ Ann. der Chemie, Bd. lix, 122. ‖ Zeitschr. für physikal. Chemie, xii, 162–166, 1893.

¶ Zeit. für Physikal. Chemie, xii, 125–139, 1893.

namely, one part in 10,070 parts of water at 16·1°C. But, inasmuch as the celestite usually occurs disseminated in limestones, let us compare with the above figures concerning the solubility of celestite, some showing the solubility of calcite. Perhaps the most reliable are those of F. Kohlrausch and F. Rose,* namely, that one part of calcite is soluble in 76,924 parts of water at 15° C.

A comparison of these figures for the solubility of calcite with the highest for celestite, which are by the same authorities — Kohlrausch and Rose — shows that celestite is more than seven (7) times as soluble as the limestone rock in which it usually occurs. But in this comparison we have considered the limestone to consist of pure calcium carbonate, which is not the case. They are more or less dolomitic and also contain some silica, thus their solubility would be even less than that indicated for calcite. Of course, waters circulating in nature are never pure, but contain oftentimes, among other compounds in solution, varying amounts of carbon dioxide, which increases to a very considerable extent the solubility of the carbonate rocks. The porous character of these rocks, however, shows conclusively that there is not enough of the carbon dioxide in the percolating waters to cause the limestones to dissolve more readily than the celestite. We can, also, readily see that in order to account for the comparatively easy solubility of celestite over the carbonate rocks, it is not at all necessary to assume the presence of extraordinary amounts of sodium, calcium, or magnesium chlorides in the circulating water.

Thus, by the continued action of water, the celestite disseminated in the strata near the surface, would pass into solution, and as this descends the mineral may, under certain conditions, be again deposited. In this way, the occurrence of celestite in the cracks and cavities is to be explained. The same explanation also applies to the "Crystal" cave. This cave, the ceiling of which is perhaps 15 to 20 feet below the surface, is a large cavity. Into this large cavity or cave, water containing celestite in solution, which was obtained from the overlying strata, flowed, and from it the large crystals crystallized. These large and well-developed crystals indicate that crystallization took place without any serious disturbance or interruption, there being a continual addition of material, i. e., as fast as the celestite was deposited more was brought in by the descending water. Such occurrences of celestite—in the cracks and cavities—are of course of secondary origin.

* Zeit. für. physikal. Chemie, xii, 162–166, 1893.

Another interesting locality, where celestite-bearing rocks may be studied to advantage, is the Woolmith quarry, located in Exeter township, midway between Maybee and Scofield, Monroe County, Michigan. The geology of this county has been thoroughly studied by Sherzer and a detailed account of the various strata occurring at the Woolmith quarry is given in his excellent "Geological Report of Monroe County."* Sherzer distinguishes nine different beds at this locality and assigns them to the Monroe series, which is, doubtless, the equivalent of the Salina in New York. For this discussion, however, it is important that the strata near the surface contain a very large amount of celestite disseminated throughout them. In several specimens, taken from what Sherzer calls bed A, crystals of celestite can be easily recognized. That some substance possessing a high specific gravity is present is evidenced by the fact that several determinations of the specific gravity of one of the specimens gave figures as high as 3·45. These rocks are dolomitic and therefore ought to possess a specific gravity of about 2·85 to 2·90. Where they have been protected from the action of water, these rocks are compact, but where they have been exposed for only a short time they assume the porous structure characteristic of celestite-bearing rocks. As in the other localities, referred to above, many of the rocks possess cavities sufficiently well preserved so that the orthorhombic outline may be readily recognized.

In the lower beds many cavities of an irregular nature, varying from a few inches up to a foot or two, are found. In these cavities beautiful crystallizations of celestite are to be noted. In some instances, the crystals are from four to six inches in length. Associated with the celestite there oftentimes occurs a considerable quantity of native sulphur and also, now and then, small amounts of calcite. The celestite is, however, by far the predominant mineral.

At this locality the changes, which are now actually taking place, may be followed very easily and furnish the best of evidence in proof of the solution of celestite in the strata near the surface and deposition in the lower and cavernous beds. The well-developed crystals of celestite, — in some cases four to six inches in length — which are found in these larger cavities in the lower strata, are therefore the result of transportation by means of solution from the higher to the lower layers of rock, and not, as Sherzer† suggests. due to the interaction in these cavities of a solution of gypsum with another containing a soluble salt of strontium. That the celestite has actually gone into solution is shown, first, by the pecu-

* Part I, volume viii of the Geological Survey of Michigan, 1900.
† Geological Report of Monroe County, 1900, 208.

liar porous structure of the leached rocks, and secondly, that many celestite veins can be found crossing the various strata, usually in a vertical direction.

As already said, many of these leached rocks possess cavities with outlines well enough preserved so that no doubt exists as to what the mineral was which originally occupied them. The best of such cavities, which have been studied thus far, are usually quite small. In many instances cavities are encountered which cannot be readily recognized as having been caused by the solution of celestite. Some of these appear as though the point of a knife had been thrust into the rock material while in the process of hardening, and on this account the term "gashed" dolomites has been used by Lane, Sherzer and others.

Sherzer* refers especially to such an occurrence at the Ida quarries, likewise in Monroe County, but adds that such phenomena can be seen throughout the whole Monroe series. In fact, this peculiar structure has been observed in many places in Michigan. Winchell in his report of 1860 calls it an "acicular" structure. He thought that gypsum was the original occupant of the cavities. Later on, Rominger also used the term acicular but made no definite statement as to what mineral had occupied the cavities. Lane,† however, mentioned calcite as possibly having been the original occupant. One of the difficulties in recognizing the original occupant of such "gashed" cavities has been due to the fact that the orthorhombic outline is not always definitely preserved. Sherzer aptly describes them as follows: "The rock looks as though, when it was only very slightly plastic, it had been jabbed in every direction with a thin-bladed, doubled-edged knife point. The gashes are always open, intersect one another irregularly and vary greatly in size, some being two-thirds of an inch long, while others can scarcely be seen without the magnifier. The cross-section of each gash shows that it is thickest at the center and that it slopes gradually and symmetrically to a very thin edge." Such an outline can be readily referred to celestite, when we bear in mind that crystals of this mineral are often found which have a tabular habitus, that is, the basal pinacoid is predominant. Cross-sections through such tabular crystals would conform very closely indeed to Sherzer's description above of the so-called "gashes."

Another reason why the original occupant of these cavities evaded detection lies in the fact, that celestite had not up to the present time ever been noted as occurring in these rocks in a disseminated condition, that is, in a condition of primary origin. Therefore, with these facts before us, first, that celes-

* Geological Report of Monroe County, 1900, 85.
† Ibid., foot-note, p. 86.

tite does occur very extensively in the dolomitic limestones of the Monroe series in a disseminated condition, and secondly, that when the mineral is thus disseminated it is usually in the form of well-defined crystals of either a prismatic or tabular habitus, and thirdly, that since celestite is, as previously shown, quite readily removed by the continued action of water, *we have every reason to believe that the phenomenon referred to as "gashing" or "acicular structure" has been produced by the mineral celestite.*

2

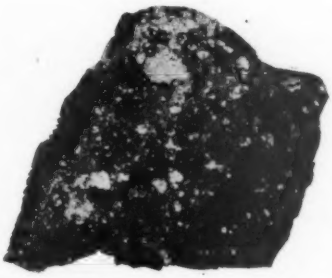
As previously noted, the celestite in these three localities occurs in a so-called disseminated condition, that is, the mineral is distributed throughout the rock. Figure 2 represents a specimen from Jamesville, N. Y. The rock is a drab dolomitic

3 4

limestone. The cavities, as can be readily seen, are all sharp and angular, and range from one-quarter of an inch up to an inch or more in size. In the interior of these specimens a considerable

amount of celestite is still present. Figures 3 and 4 represent a specimen (two views) from Split Rock, a short distance west of Syracuse, N. Y. In this specimen a very large percentage of the rock was celestite, as is indicated by the large number of cavities. In the interior the mineral is still to be seen. A comparison of these figures (3 and 4) with figure 1 shows that a very close similarity exists between the two occurrences. Figure 5 shows another specimen from Jamesville, N. Y.,

5



where the celestite appears disseminated in small irregular spots.*

A study of these and other specimens shows first, that the celestite is or was actually distributed throughout the rock, or in other words, imbedded in the rock; second, that the cavities, which remain after the mineral has been removed by solution, conform for the most part to the original outline of the celestite; and thirdly, that many of these cavities are very sharply defined, being bounded by smooth surfaces. Therefore, the conclusion is forced upon one that *the celestite was no doubt deposited simultaneously with the rock material, and also that as the crystals of celestite formed, the soft rock material yielded and surrounded them on all sides. Such occurrences may, hence, be considered of primary origin.*

Further investigations as to the crystallography of the celestite in these localities, the amounts of the mineral actually present in the rocks and the origin of the sulphur which is associated with the celestite, especially at the Woolmith quarry, are in progress in this laboratory and will be reported upon as soon as feasible.

I am indebted to Dr. G. P. Burns for the photographs which accompany this paper.

**Mineralogical Laboratory, University of Michigan,
Ann Arbor, Mich., January, 1905.**

***Compare figs. 1, 3, 4, 5 with those shown in a previous paper "The Occurrence of Celestite near Syracuse, N. Y., etc.," this Journal, lviii, 31, 33, 34, 1904; fig. 2 is repeated from that paper.**

Art. XXVII.—*A Note on Interference with the Bi-Prism;* by William McClellan.

In most descriptions of interference with the bi-prism the trouble which diffraction is likely to cause receives scant attention. It is true, reference is usually made to the fringes that are commonly found to border the field, but not as if they could seriously detract from the result. Some time ago, on setting up a prism on an optical bench, a colored center was obtained, and apparently no amount of adjusting would make it appear white. This, of course, proved the presence of something other than interference, that is, diffraction. The matter was

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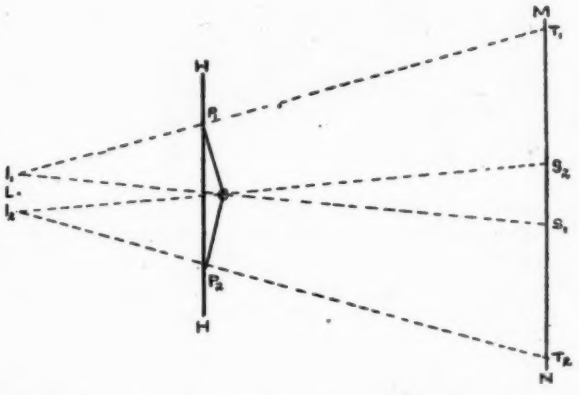

studied a little, and an explanation found which is quite simple. It is obvious that the condition of the field as obtained from a given prism depends upon the relation of the distances between the prism, screen and light. The fact is well known to many experimenters, but no detailed note has ever been observed by the writer, in any text. This is probably due to the fact that the bi-prism is a lecture-room piece rather than one for the laboratory. The following explanation is suggested.

Let L (fig. 1) be a source of light, and I_1, I_2 its two images formed by the by-prism P_1 P_2. MN is a screen. We may treat the diagram as if I_1, I_2 were separate sources, as they might be if we could arrange constant phase relations. Light coming from I_1 will light the screen from S_1 to T_1 if we consider the prism set in an opaque holder HH. Similarly, light

from I_2 will illuminate S_2T_2. The space S_1S_2 is lit by both sources and is therefore the interference field. It is necessary to notice however that as no light from I_1 can fall below S_1, the prism face OP_2 can be looked upon as an opaque screen for I_1. Consequently we find diffraction bands extending from S_1 into S_1S_2. In like manner fringes will extend inwards from S_2. Now it is easily seen that if the two sets of diffraction fringes should extend so far into S_1S_2 as to meet, there would be no clear field in which pure interference could be seen. The two kinds of bands would be superimposed, and neither would be seen as they are. This, of course, is precisely what does happen if conditions are not arranged to prevent it. It is easy to find what these conditions are.

Let the distance from light to prism be a, and that from prism to screen be b. Let the angle OP_1P_2 be e. Then if d be the angle I_1, OL and u the index of refraction, $d = (u-1)e$ which is half the angular space S_1OS_2. The half interference field on the screen is then $b(u-1)e$.

Now regarding OP_2 as a screen for the source I_1, and x as the distance of the $2n$th diffraction band from the geometrical shadow,

$$x = \sqrt{\frac{b(a+b)}{a} 2n\lambda}$$

it is evident that if we are to have an open field for pure interference, this distance x must be less than the half interference field, that is,

$$\sqrt{\frac{b(a+b)}{a} 2n\lambda} < b(u-1)e$$

or reducing

$$\frac{1}{a} + \frac{1}{b} < \frac{(u-1)^2 e^2}{2n\lambda}$$

for any given prism, u and e can be measured. n is a constant for all prisms, and is simply the number of that pair of bands for which the ratio of intensities is so close to unity as not to permit of separation by the eye. This value can be calculated or observed. Either method shows that six is a fair value for n. λ, of course, depends upon the light used. It should be noticed that while a prism with a large angle e, according to the formula, will give a clear space more easily, the interference lines will be narrower the larger the angle. This is shown by the expression for the width of interference lines, $\frac{\lambda}{2(u-1)e}$. For this reason the prisms supplied for this purpose usually have

small angles, which give wider lines but a very narrow clear space.

Figures 2 and 3 will illustrate the above discussion. They are reproduced from photographs taken on the optical bench. using the eye-piece as an objective. Figure 2 shows the two

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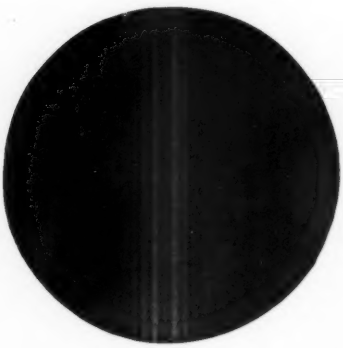

3

sets of lines superimposed; the center band could be made any color desired, by changing the distances a and b. Figure 3 shows a half field with complete separation. On the left the two sets of lines can be seen superimposed, while on the right the interference lines alone are seen. Another photograph, not reproduced, shows a whole field with very complete separation, the central portion covered with very fine interference bands.

Randal Morgan Laboratory,
University of Pennsylvania.

ART. XXVIII.—*The Doughty Springs, a Group of Radium-bearing Springs, Delta County, Colorado;** by WILLIAM P. HEADDEN.

THE group of springs, known as the Doughty Springs, is situated on the right bank of the North Fork of the Gunnison River in Delta County, Colorado, about four and a half miles from the town of Hotchkiss. They are almost wholly unknown to the public, and are but little more than objects of curiosity to the people of the neighborhood. My attention was called to them about two years ago by H. E. Mathews, in whose company I first visited them.

The odor of hydrogen sulphide is noticeable for some distance from the springs, but the extensive sinter bed is a more striking feature, especially to persons more familiar with mineral springs in general.

A superficial examination of the surroundings, particularly of the face of the cliff, which rises immediately behind the springs to a height of 130 feet, suggests even more strongly than the sinter bed, that these springs or waters from some other source are heavily charged with salts and are now acting upon the sandstones and shales to a very readily observed extent.

The sinter bed is 400 feet long by 147 feet wide, measured at the widest part, with an average width of about 115 feet. The thickness of the bed where exposed along the river is about 20 feet, but increases a little as we approach the springs, showing that a general deposition is now taking place. There is but one instance of cone building and the little streams which flow across the surface of the bed have not formed elevated margins to mark their course.

The formation of the cone about this one spring is due to the fact that it is surrounded by a rank-growing grass, whose leaves and stems falling about it serve to catch and hold the sinter-forming material until cemented together, forming quite a compact sinter.

The sinter bed extends from the springs, which are situated near the base of the cliff, to the river, where it forms an almost perpendicular face. The river has encroached upon the bed by undermining and causing the overhanging sinter to

* An abstract of a paper read before the Colorado Scientific Society, Jan. 13, 1905. This paper was presented by permission of the President of the College.

break off; such broken-off pieces, 20 feet in width, are still remaining.

The cliff rises perpendicularly to a height of 130 feet immediately back of the springs, but is higher at points both above and below them; in structure it presents an alternation of sandstones and shales with a stratum of conglomerate near the top. This series probably belongs to the upper portion of the Dakota.

While the flow from the individual springs is not notably large, the aggregate flow of the group is very considerable. The large number of small springs in the group is probably due to impeded outflow, whereby the waters are forced to find various passages for their escape. According to my information, one spring issues in the bed of the river. All of the springs emit gases in moderate quantities, but the emission is continuous. In addition to the flow of the springs proper, small streams are issuing from the face of the sinter bed at very many places, in fact, almost throughout its entire length. Assuming this water to come from the springs, their actual discharge must be quite large, but it is not certain that this assumption is wholly correct. I have no doubt but that waters coming from the cliff, including some surface waters, do find their way into the springs under the present conditions, but the amount of this water is wholly insignificant, and without influence upon the flow of the springs. While I do not think that there is any significant quantity of surface water finding its way into these springs, it does seem probable that some of the waters represent mixtures of different springs. It is clearly evident that there are three distinct types of water represented by the analyses which I shall give. There is, however, a number of springs, how many I do not know, whose waters are intermediate in character between two of these types.

The gases emitted by these springs consist largely of carbon dioxide and hydrogen sulphide, but I have not yet submitted them to an examination. I am of the opinion that they will prove to be as interesting as the waters themselves or their deposits.

These springs are, so far as the writer is aware, wholly unknown to the general public, and have no individual names, but are spoken of collectively as the Doughty Springs. It is true that one of them is called the Black Spring, because the water as it lies in a basin adjoining the spring proper appears black; another is called the Bath Tub, because of its size and convenient depth for bathing; also, because there are good reasons to believe that the Indians used it for this purpose, for according to Mr. Doughty, the mud which had gradually

collected in the bottom of the spring was found to contain an abundance of beads and Indian trinkets lost by the bathers. The Indians attributed great medicinal virtues to this and to the other springs also. A third spring is called the Drinking Spring, because the water of this spring is preferred to that of any of the others for this purpose. I do not know the reason for this choice, but those who are accustomed to it drink it very freely. This preference is probably another instance in which the general judgment has arrived at a correct scientific conclusion based upon some effect which it either cannot or never troubles itself to formulate. It will appear later that this is the most remarkable spring in the group and constitutes one of the three types to which I have alluded.

There are but three springs in the group whose waters are clear; they are the Black Spring, the Drinking Spring, and a smaller one designated the Alum Spring. The other springs show a pronounced milkiness. The presence of hydrogen sulphide would, according to general observation, account for this, especially in the case of springs having a small flow and presenting a large surface to the air, such as the Bath Tub, whose diameters are 19 and 27 feet respectively. Some of the smaller springs, however, having a comparatively large flow of water and gases—conditions tending to reduce this degree of milkiness, are more turbid than the Bath Tub, and suggest that the presence of hydrogen sulphide is not the cause of the milkiness, which is really the case. I shall subsequently show that it is almost wholly due to the separation of baric sulphate and not to sulphur set free by the decomposition of hydrogen sulphide.

The Black Spring is clear, but it is forming little or no deposit from its waters. While there is some deposit formed on the shale through which the spring issues, this deposit is almost pure sulphur and undoubtedly owes its origin to the oxidation of the sulphide. This spring has a basin contiguous to it, but the deposit forming in this is black (from which fact the spring obtains its name), and consists essentially of ferrous sulphide with manganous sulphide and a trace of zinc sulphide. The Alum Spring is clear, but its deposits are of an entirely different character from the sinter formed by the other springs. The Drinking Spring is perfectly clear and sparkling, and is actively depositing sinter outside of the spring. This sinter is practically pure baric sulphate.

The milkiness of the other springs is due to the separation of baric sulphate in an extremely fine state of division: this separation probably takes place before the waters actually come to the point of their discharge. The cause of the sep-

aration is probably to be found in the mingling of waters from different springs quite near to the surface. We have the Drinking Spring at one end and the Black Spring at the other, both clear, while the intermediate ones are turbid. The water of the Black Spring is different from that of the Drinking Spring, and a mixture of these waters would bring about the precipitation of baric sulphate. The precipitated baric sulphate is in an extremely fine state of division, and the flow of water and gas is sufficient to keep it in suspension and produce the milky appearance of the water.

The considerations which lead me to this conclusion are the following:

The Drinking Spring is perfectly clear and contains a very marked quantity of barium in solution. This spring is depositing a baritic sinter outside of the spring.

The other springs are turbid or milky. Their waters contain only a very minute trace of barium after the milkiness has disappeared. A baritic sinter is forming in and about these springs.

A spring designated as the Birds Nest is building a cone about its vent consisting very largely of baric sulphate precipitated within the spring and washed up and out by the outflowing gases and water. The water contains only a minute trace of barium.

A small amount of deposit was obtained from five gallons of water dipped from the Bath Tub; this deposit contained in whole numbers 25 per cent of baric sulphate and only a minute quantity of sulphur. The fine impalpable mud from the bottom of the Bath Tub contained almost 40 per cent of baric sulphate.

The foregoing facts convince me that the explanation offered to account for the milkiness of these springs is correct. It further seems to me to follow that water similar to that of the Drinking Spring is the source of the barium, while the precipitant is probably a water of the type of the Black Spring. If the precipitation takes place very near to the surface, it is possible that water of surface origin may participate in the precipitation.

I cannot give the number of springs in this group. The strip extending from the Drinking Spring to the Black Spring, a distance of 150 feet or more, is an area of general discharge with a number of well defined springs.

The waters of these springs are, at first, not very acceptable to the palate and the average person would have to acquire a taste for them. The characteristic in their taste is not due to the hydrogen sulphide. I do not know to what one can liken their taste, especially that of the Drinking Spring, which sug-

gests to me simultaneously the taste of hydrogen sulphide and that of hydrogen peroxide.

All the springs of this group with the exception of the Alum Spring furnish drinkable waters, but the preferred ones are the Drinking Spring and the Black Spring. The water of the Alum Spring is so astringent that its character becomes apparent to one immediately upon tasting it.

Black Spring.

This is the most westerly spring of the group of any size; its diameters are 30 and 48 inches respectively. The flow is not very strong and is accompanied by a continuous but moderate discharge of gas. The water is clear and has a temperature of 17·5° C.

The presence of the following substances is not noted in the analyses: sulphides other than hydrogen sulphide; titanic, phosphoric, and dithionic acids. I could not examine the waters until the samples had become so old that a determination of the sulphides and the dithionic acid would have been of but little or no value.

I determined the dithionic acid in the water of the Black Spring while the sample was comparatively fresh; its value, however, is not great, for the sample was already several days old. Phosphoric acid is present in minute traces; titanic acid also, but the reactions for the latter were very faint, and may have been erroneously interpreted. I did not detect either caesium or rubidium in the amounts of water used, from three to six liters.

ANALYSIS OF BLACK SPRING.

Calculation of Cations.

	Per liter.		Monivalent ions.
Na	1·1978	0·051964	0·051964
K	0·0589	0·001504	0·001504
Li	0·0016	0·000224	0·000224
NH_4	0·0013	0·000074	0·000074
Ca	0·1261	0·003152	0·006304
Ba	None		
Sr	0·0035	0·000039	0·000079
Mg	0·0609	0·002500	0·005000
Fe	0·0012	0·000021	0·000042
Al	0·0046	0·000168	0·000504
Mn	0·0040	0·000072	0·000144
Zn	Trace		
Sum	1·4599		0·065839

Calculation of Anions.

	Per liter.		Monivalent ions.
Cl	0·8157	0·023009	0·023009
Br	0·0147	0·000184	0·000184
I	Trace		
SO_4	0·2731	0·002843	0·005686
SiO_3	0·0235	0·000308	0·000616
BO_3	0·0001	0·000003	0·000003
S_2O_3	0·0108	0·000096	0·000182
Sum	1·1397		0·029680

Sum of cations	0·065839
Sum of anions	0·029680
Excess cations	0·036159

The excess of cations, 0·036159, equals CO_3 ions expressed as monivalent ions or 0·018079 bivalent ions corresponding to 1·08474 grams CO_3 equal to 0·794438 gram CO_2 combined as neutral carbonates.

Total CO_2 found was	2·5660
CO_2 combined as neutral carbonates	0·7944
	1·7716
CO_2 combined as bicarbonates	0·7944
CO_2 wholly free per liter	0·9772

The CO_2 wholly free corresponds to 496·84^{cc} per liter at 0° C. and 760^{mm} pressure.

Hydrogen sulphide considered as wholly free equals 0·0492 gram or 32·12^{cc} per liter. Specific gravity at 16° 1·00400. Total solids 3·6825 grams per liter.

The Drinking Spring.

The water of this spring is by far the most interesting one of all the group: it is clear and limpid with a decided odor of hydrogen sulphide. The discharge of gas is moderate but constant. There are smaller springs of the same character in its immediate vicinity. The spring is nearly circular with a diameter of 12 to 14 inches.

ANALYSES OF DRINKING SPRING.

Calculation of Cations.

	Per liter.		Monivalent ions.
Na	1·0571	0·045863	0·045863
K	0·0617	0·001576	0·001576
Li	0·0031	0·000446	0·000446
NH_4	0·0012	0·000068	0·000068
Ca	0·1057	0·002636	0·005272
Ba	0·0132	0·000096	0·000192
Sr	0·0066	0·000075	0·000150
Mg	0·0394	0·001615	0·003230
Fe	0·0007	0·000013	0·000026
Al	0·0005	0·000018	0·000054
Mn	0·0016	0·000030	0·000060
Zn	Trace		
Sum	1·2908		0·056937

Calculation of Anions.

Cl	0·7005	0·019762	0·019762
Br	0·0052	0·000065	0·000065
I	Trace		
SO_4	0·6252	0·006511	0·013022
SiO_2	0·0266	0·000348	0·000696
BO_2	0·0075	0·000174	0·000174
Sum	1·3652		0·033719

Sum of cations	0·056937
Sum of anions	0·033719
Excess of cations	0·023218

The excess of cations, 0·023218, equals CO_3 ions expressed as monivalent ions or 0·011609 bivalent ions corresponding to 0·69654 gram CO_3, equal to 0·5108 gram CO_3 combined as neutral carbonates.

The total CO_3 found was	3·0800 grms.
Less CO_3 combined as neutral carbonates	0·5108
	2·5692
Less CO_3 combined as bicarbonates	0·5108
CO_3 wholly free per liter	2·0584

The CO_3 wholly free, 2·0584, corresponds to 1047·53^{cc} at 0° C. and 760^{mm} pressure.

The hydroden sulphide considered as wholly free equals 0·0471 gram per liter equal to 30·88^{cc} at 0° C. and 760^{mm} pressure. The specific gravity at 15·5° was 1·00377. The total solids = 3·3525 grams per liter.

Deposits of various salts occur rather abundantly on the face of the cliff; these are for the most part easily soluble salts, but some of them are more difficultly soluble. Gypsum occurs occasionally but is not common.

These salts might owe their formation to surface waters finding their way through the strata to the face of the cliff. The dip and character of the strata are such that if this be the case the waters must come from considerable distances. On the other hand, the waters saturating the strata might be spring waters, in which case the incrustations ought to resemble the deposits from the spring waters. These considerations motived me to examine a few of these deposits and led to some very interesting observations.

An incrustation occurring on the face of the sandstone stratum 150 to 200 feet east of the Drinking Spring and five feet or more above the upper margin of the talus soil was found to contain 2·50 per cent of sulphur with calcium, barium, potassium, lithium and sodium. Though this sample was collected 150 feet or more from the nearest observed spring and from the face of a compact sandstone stratum under conditions precluding accidental deposition, its qualitative composition is strongly suggestive of the matter held in solution by the water of the Drinking Spring. The appearance of this incrustation on the face of the sandstone fairly raises the question of the source of these waters, i. e. are they waters finding their way along and through the strata, or are they forced into the strata from below? I am inclined to the view that they come from greater depths, but the springs themselves do not indicate a high pressure.

Another sample collected 50 feet or more up on the face of the cliff proved to be the mineral mirabilite. It was well crystallized and was not associated with other minerals. It is not at all rare to find this mineral deposited from some of our alkali waters in crystals five or six inches long, but in this case it probably came from the stratum of shale.

Another deposit collected from the rocks at the base of the cliff immediately back of the Black Spring had an entirely different composition. It was this that led me to examine the water designated as the Alum Spring.

This deposit occurred associated with well defined crystals of gypsum; it was white, pasty, and astringent to the taste. When a coil of clean iron wire was brought into its aqueous solution, hydrogen was set free quite rapidly. A solution of

aluminic sulphate treated in this manner will liberate hydrogen, but not nearly so rapidly as this solution. A comparative test showed the evolution of hydrogen from a solution of aluminic sulphate to be less than one fifth as rapid. This deposit placed in contact with cotton cloth or paper destroys it.

The analysis of this sample presented some difficulties and the footing of the analysis is over one hundred. The sample was dried for three days at the temperature of the room; its weight was nearly constant during the last day.

The analytical results were as follows:

	Per cent.
Loss on drying in water oven for ten hours	29·61
Loss on drying in air-bath at 147° for two hours	15·35
Insoluble in water	2·72
SO_3	32·89
Fe_2O_3	1·16
FeO	Trace
Al_2O_3	6·71
CaO	0·69
MgO	3·33
Na_2O	4·68
K_2O	0·32
Li_2O	Heavy trace
Ignition with addition of lead oxide	4·45
	101·91

The reactions of this material are those of an alum, and the composition is between that of mendozite and pickeringite. The material did not seem to me to justify a repetition of the analysis, especially as I intended to visit the locality again to determine, if possible, whether there is a spring at this point whose waters would account for the formation of such a deposit as this. On my next visit I found that heavy rains following periods of freezing and thawing had caused large quantities of material to come down from the cliff above, and the point where I had obtained this sample was covered deeply under mud and rocks. We succeeded in digging two holes from which we obtained samples of water: one of them was clear but the other was turbid, due to the presence of a white precipitate. Neither of these samples was satisfactory, but I could not obtain better ones. The following analysis serves thoroughly well to show the character of the water collected, though it is not so complete as some of the others. The sample was not from a definitely located spring, and the analysis given is of as much value as a fuller one would be.

ANALYSIS OF ALUM SPRING.

Cations.

	Per liter.		Monivalent ions.
Na	0·4561	0·019786	0·019786
K	0·0216	0·000551	0·000551
Ca	0·4089	0·010198	0·020396
Mg	0·1888	0·007750	0·015500
Fe	0·1485	0·001860	0·003720
Al	0·3036	0·011203	0·033609
Sum	1·5275		0·093562

Anions.

Cl	0·2790	0·007869	0·007869
SO_4	3·5275	0·036608	0·073216
SiO_2	0·0745	0·000975	0·001950
	3·9810		0·083035

Sum of cations	0·093562
Sum of anions	0·083035
Excess of cations	0·010527

The excess of cations, 0·010527, expressed as monivalent ions correspond to 0·005264 bivalent CO_3 ions or 0·2316 gram CO_2 per liter as neutral carbonates. Specific gravity at 15·5° C. 1·00546. Total solids 5·7401.

If the calcium were removed from this water in the form of gypsum it would give rise to just such a mixture as we actually found.

The sample which remained milky was not analyzed, but it was thoroughly shaken and a portion of it filtered, and the white precipitate examined; it consisted principally of aluminic hydrate.

As the point at which I had formerly found the white, pasty mass, an analysis of which has already been given, was buried under a mass of débris, I of course failed to obtain more of it, but I found at this place masses of the mineral alunogen. This mineral occurs abundantly at the base of the conglomerate previously mentioned, and the specimens found at this time may have come from this source.

The most interesting feature of these springs is the sinter bed which they have formed, of which there is probably more than a million cubic feet remaining at this time. An analysis of a general sample taken from the face next to the river gave the following results:

ANALYSIS OF GENERAL SAMPLE OF SINTER FROM FACE OF BED NEXT TO THE RIVER.

	Per cent.
Sand and SiO_2	0·51
Organic matter	2·29
CO_2	39·39
Cl	Trace
SO_3	Trace
CaO	48·84
SrO	1·16
BaO in HCl solution	Trace
MgO	1·37
Fe_2O_3, Al_2O_3	0·20
MnO	0·62
Na_2O	Trace
Li_2O	Trace
$BaSO_4$	5·42
	99·80

Other general samples from different parts of the bed were tested and baric sulphate found to be present in all of them, the percentage ranging from 3·25 to nearly 10·0 per cent. As the sinter was richer in baric sulphate as we approached the end of the bed where the Drinking Spring is located, I took two samples, one from near the spring and the other at the spring, and analyzed them with the following results:

ANALYSIS OF SINTER TAKEN 8–10 FEET FROM THE DRINKING SPRING.

	Per cent.
Organic matter with a little free sulphur	3·43
$CaCO_3$	26·46
$BaSO_4$	66·98
Fe, Mn, Na, K and Li not determined	[3·13]
	100·00

ANALYSIS OF SINTER TAKEN WITHIN 2½ FEET OF THE RIM OF THE DRINKING SPRING.

	Per cent.
Organic matter with a little sulphur	3·11
$CaCO_3$	1·84
$BaSO_4$	94·62
Mg, K, Na and Li	Traces
	99·57

The spring designated the Bird's Nest is building a cone of this baritic sinter: it has the following composition:

	Per cent.
Organic matter, etc.	7·82
$CaCO_3$	43·39
$BaSO_4$	48·79
Sr, K, Na and Li	Traces
	100·00

The Bath Tub furnishes the finest samples of this baritic sinter. The spring is lined with a pure cellular barite. The sample which I used as a source of this barite for analysis was from the Bath Tub, but was chosen to represent an average sample of this sinter as it occurs near the springs.

ANALYSES OF SINTER FROM THE BATH TUB.

	Per cent.
Soluble in acetic acid	15·46
Soluble in HCl conc., not soluble in acetic	1·33
Insoluble, $BaSO_4$	83·21
	100·00

Analysis of the insoluble portion.

SiO_2	3·25
SO_3	32·25
Al_2O_3, Fe_2O_3	0·80
BaO	63·00
CaO	0·30
SrO	0·45
MgO	Trace
K_2O	0·17
Na_2O with heavy trace of lithia	0·29
	100·51

The barium determination is too high; the chromate should have been reprecipitated a second time.

The examination of these samples of sinter show that the bed passes from a calcareous sinter carrying a few per cent of baric sulphate to a pure barite sinter at some of the springs. This I believe to be a unique fact. Frequent mention is made of the occurrence of barium in mineral springs, mostly in traces, but I have found mention of only one water which deposited baric sulphate, a mine water in England.

I have stated that I regret not having yet examined the gases given off by these springs. I am fully convinced that they contain helium, for these waters contain, as I shall now show, comparatively abundant quantities of radium.

The close relationship between barium and radium and the well-known fact that barium possesses the property of carrying down other substances with it when precipitated from its solution and radium in a very high degree, made it almost certain that I would find this sinter to contain radium provided any at all were present in the springs.

I was forced to depend upon its action on the photographic plate in testing for it. The action of the sinter as it was broken from the bed, always from points near or at the springs, was of course weak compared with the action of Gilpin County pitchblende, but it was always present and could be seen during the development of the plate even if it were invisible after fixing and drying,

In one experiment made to test the action of the sinter in comparison with that of pitchblende the plate was covered with two thicknesses of black paper and a piece of pasteboard and the exposures made for five days; the radiograph obtained with the pitchblende was distinct but not sharp; the plate exposed to the action of the sinter showed the stencil used while it was being developed, but not when fixed and dried.

I next undertook the preparation of radiferous barium chloride. For this purpose I fluxed 13 pounds of sinter with sodic carbonate, washed, dissolved in HCl, removed silica and iron by usual methods and crystallized out the baric chloride; the yield of crude $BaCl_2$ was eight pounds. This was subjected to fractional crystallization at last from HCl solution. When the mass of $BaCl_2$ amounted to rather less than 2 ozs. it was allowed to stand for 15 days to regain its β and γ rays and then tested. This preparation gave an impression upon the plate after an exposure of $2\frac{1}{2}$ days comparable to that made in five days by pitchblende. The distance between the film and the salt was from 0·25 to 0·5 centimeters and the plate was covered with two thicknesses of black paper. I did not deem it necessary to carry this work further for the purposes of this immediate work.

So far as I am able to discover, this group of springs is unique in that it is depositing a baritic sinter, and also in the presence of radium in comparatively large quantities.

State Agricultural College,
Fort Collins, Colorado.

Art. XXIX.—*The Error of Collimation in the Human Eye;* by C. S. Hastings.

[The references H in the following pages are to the Handbuch der Physiologischen Optik von H. von Helmholtz. Zweite Auflage, 1896.]

One of the most curious imperfections of the human eye, of the many discovered or investigated by Helmholtz, is that of an unfailing inclination of the line of sight to the axis of symmetry of the cornea (H. p. 17), or, what appears to be essentially the same thing, to the geometrical axis of symmetry of the whole eye (H. pp. 108, 109). There is, it is true, no reason for surprise that such an error should exist, since, if we suppose, as we are obliged to do, that the present structure of the eye is the result of a long process of evolution, we ought to expect the survival of imperfections which, too minute to impair the effectiveness of the eye as a sense organ, would therefore be too minute to serve as incentives to farther development. Such surviving imperfections would be called errors when we regard the eye as an optical instrument; and Helmholtz has shown that no error which can be named by the optician is absent from the eye. On the other hand, this eminent investigator has shown that these errors are always so small, in a normally formed eye, as not to impair the precision or visual perceptions with the eye of its present size. This point may be emphasized by the following consideration. If it were required to remodel the eye so as to double its present power, it can easily be shown that this would necessitate an increase of volume to fifteen or twenty times its present value. In view of the enormous difficulties to be met in nourishing and protecting such an organ with a retention of its transparency, we may well conclude that the balance between physiological cost and utility has already been attained, in short, that the closest approach to practical perfection has been reached long ago, even in the protracted history of evolution.

The particular error, however, which is the subject of our consideration and which would be known to opticians as an error of collimation, is distinguished from nearly all others in two peculiarities; first, it is the easiest of all errors in an ordinary optical instrument to eliminate, and second, it is systematic, i. e. it is of such a character that the axis of vision always lies on the nasal side of the geometrical axis outside of the eye. It is this systematic character of the error which gives it its particular interest and for which we feel ourselves prompted to seek a reason.

The first step in an investigation with this end in view is to find the average value of the error. Helmholtz himself (H. p.

19) measured this angle for three eyes only, but Dr. Uhthoff (H. p. 22) adds four, and H. Knapp (H. p. 109) gives data from which we may deduce, with considerable confidence, four more. We thus have eleven cases of which the average value of the angle (α) is 5°·36. This is an insufficient number to serve as the basis of any important conclusions, especially in view of their great irregularity of values; it seemed desirable, therefore, to collect a larger number of instances. In this work Professor F. E. Beach kindly aided me with great skill, and to him is due more than half of all the measurements of which the results follow.

The method employed was quite like that devised by Helmholtz (H. pp. 15–19), except that we used a filar micrometer instead of an ophthalmometer. Both methods were tried, but, notwithstanding the obvious advantages of the double image instrument, the former was found quite as accurate and materially more rapid. With this arrangement we found for 52 eyes the following results:

I. There was no case of reversal in sign of α, that is, the axis of vision, extended outwards, always lies on the nasal side of the axis of symmetry of the cornea.

II. The value of α varies greatly. The smallest value which we found was 1°·25 and the largest 7°·76. There was no evidence of a systematic difference in the numerical values of the angle for the right and the left eye.

III. The mean value for the 52 eyes examined was 3°·98.

The mean value is much less than that of the German measures; this may be owing to racial differences—it is well known that the average separation of the eyes is less for Americans than for Germans—or it may be owing simply to the small number of cases in the earlier group. However this may be, it seems that the best attainable value at present is the weighted mean of these two averages, namely:

$$\alpha = 4°{\cdot}2$$

We shall assume in our further studies, therefore, that a line drawn from the second nodal point in the normal eye to the center of that small region of the retina to which the sharpest visual perceptions are confined—the *fovea centralis*—lies wholly on the temporal side of the geometrical axis of the eye and inclined to it at an angle of 4°·2; moreover, as necessarily involved with this assumption, that a line drawn outwards from the first nodal point to the point of fixation lies wholly on the nasal side of the axis at the same angle of inclination. This angle we may call, for convenience, the constant of collimation for the normal or schematic eye (H. p. 140).

Closely connected with the constant of collimation in the discussion of a variety of optical phenomena which I shall con-

sider later, is the question of the position of the pupil of the eye. Here too, we lack sufficient data for establishing any conclusion. As far as is known to me, only three eyes have been investigated in this particular, and all of these by Helmholtz (H. p. 29); and as he found in two of the three that the center of the pupil falls very near the axis of vision, and in the third very near the axis of the eye, no result could be less determinate. Were the base of the cornea centered upon its axis of rotation as Helmholtz concluded from his limited number of observations (H. p. 19, relation of angles α and β), the determination of this element would be very easy; indeed, a simple inspection shows that the pupils of practically all eyes, at least when not dilated, are strongly displaced towards the nasal side of the iris. But we found no such simple relation between the axes of the cornea and of the iris; hence it seemed necessary to make a rather extended series of measures for a foundation for precise conclusions.

Helmholtz's method of determining this element by use of his ophthalmometer is somewhat laborious and subject to considerable uncertainties, if not to errors, from changes in pupilar diameter during the measurements. This consideration, together with the fact that statistical information founded upon numerous observations of moderate accuracy is of far greater value than an accurate determination of individual peculiarities, led me to adopt a different method, which may be described as follows.

A telescope provided with a filar micrometer is placed at a distance from the eye to be measured, which is large compared to the linear dimensions of the eye. The telescope has directly below its objective a small adjustable mirror which, illuminated by a conveniently placed light, serves as a luminous source itself. When the observed eye is fixed upon the middle of the objective of the telescope, the observer sees, with properly adjusted telescope, a sharply defined image of the pupil with a bright point image of the mirror near its center. Two parallel wires of the micrometer are brought within a convenient small distance of each other, and the telescope so directed that these wires appear to be symmetrically placed upon the pupil; then the point image will, in general, appear to lie slightly on the nasal side of a point midway between the wires. In a few cases the bright point will appear exactly half way between the wires, and even, in very exceptional cases, with a very slight displacement towards the temporal side.

Fig. 1 illustrates the general appearance when the nose lies in the direction indicated by the arrow. When a satisfactory adjustment of this kind is secured, an estimate is made of the apparent displacement of the center of the pupil towards the

temporal side in terms of tenths of the separation of the wires. A subsequent determination of the absolute value of the interval between the wires yields the real displacement. In the observations which were made by Professor Beach, as well as in those made by myself, the reduced interval was ·075^{cm}, so the probable error of our measures may be estimated at about one-tenth of this quantity.

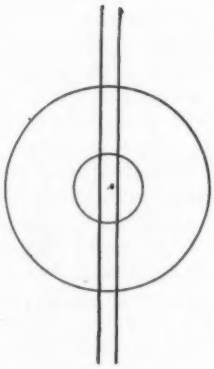

FIG. 1.

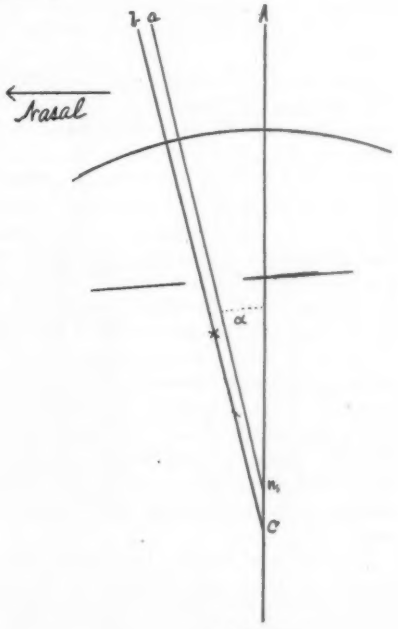

FIG. 2.

In the reduction of the observations it was assumed that the radius of the cornea was, in every case, the same as that of the schematic eye, namely, 0·7829^{cm}. Such an assumption was not necessary, since it would have been easy to determine this element for each case, but it was convenient and could lead to no error which could become significant in any considerable group of measures. The method of reduction will appear from reference to fig. 2. Here AC represents the axis of an eye with the geometrical center of the cornea at C and its first nodal point at n_1. The direction $n_1 a$ will be that of the source of light and of the observing telescope. The image of the source of light

will lie on the line C*b*, which is essentially parallel to $n_1 a$, at a point midway between C and the surface of the cornea. Now if the center of the pupil were on the line of vision $n_1 a$, it would appear displaced towards the temporal side by a distance equal to the interval separating $n_1 a$ and C*b*, or by n_1C sin *a*. In the schematic eye the distance from n_1 to C is $0{\cdot}0861^{cm}$. Since *a* is known for all the eyes observed, the relation of the position of the center of the pupil to the point where the line of vision pierces the plane of the pupil is readily determinable.

The results from the forty-eight eyes thus investigated appeared highly irregular. Yet a careful analysis brings us to a conclusion which may be stated with considerable precision. There were only two eyes in which the centers of the pupils were found to be quite certainly, although by a small amount, on the temporal side of the axis of symmetry, and these belonged to different individuals. On the other hand, only a single eye was found to have the center of its pupil quite distinctly on the nasal side of the line of vision, a peculiarity not shared by its companion. In this exceptional case the apparent displacement towards the nose was strikingly obvious to every casual observer. The mean position of all the forty-eight was almost exactly midway between the axis of symmetry and the line of vision. This relation, so simply stated, was not dependent upon the value of *a*. This was proved by the fact that when all the observations were arranged in three equal groups according to small, medium and large values of the constant of collimation, each group was found to yield almost exactly the same rule.

The center which has been determined is, of course, the center of the virtual image of the pupil as seen through the cornea; but the rule holds true also for the real position of the pupil. It is not improbable that the center of a dilated pupil is not in quite the same place as one adjusted to a well-lighted room, but that is of minor importance in the questions which have led to this investigation.

For a further study of certain phenomena of vision I shall assume, as a generalization of the schematic eye of Helmholtz:

1st. That its constants as regards accommodation and wavelengths are defined by the tables given in the preceding number of this Journal.

2d. That the collimation error is $4°{\cdot}2$ on the nasal side.

3d. That the pupil is centered on a line which bisects the angle between the axis of symmetry and the line of vision.

Yale University, March, 1905.

Art. XXX.—*A New Form of Electrode for Lead Storage Cells;* by H. M. Dadourian.

It was desired to build up a battery of lead storage cells, to be used in the Sheffield Physical Laboratory, for constant potential. After considering several types of cells, one described by Feussner* was adopted. But the electrodes of these cells

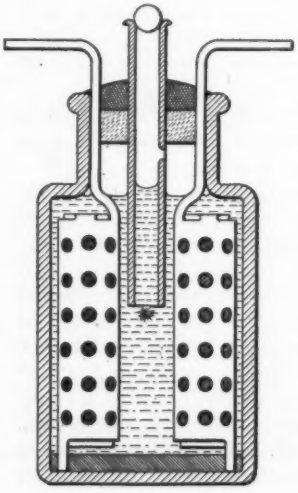

Fig. 1

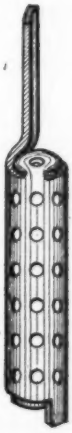

Fig. 2

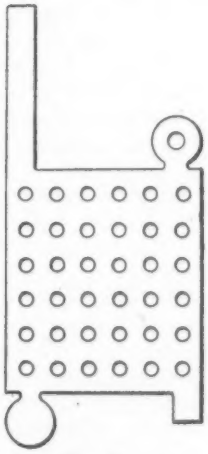

Fig. 3

were inconvenient on account of the falling off of the paste. This objection was done away with by designing a new form of electrode, which has given such satisfactory results that it is thought it may be of interest to others.

A meridian section of a complete cell is shown in fig. 1. Fig. 2 is a perspective view of one of the electrodes, which are 50^{mm} long and are cut out of lead tubing 12^{mm} in diameter.

After being packed up with a paste made of lead oxide (litharge) and sulphuric acid of sp. gr. 1·20, a couple of these electrodes are placed in a glass bottle, 80^{mm} high and 45^{mm} in diameter. The electrodes are held in position by means of a layer of pitch at the bottom and a cork in the neck of the bottle. A small hole in the middle of the glass tube, which is in the center of the bottle, serves as an outlet for the gases which form in the cell.

* Feussner, Sammlung Electrotechnische Vorträge, vol. i, p. 139.

The electrolyte, which is sulphuric acid of sp. gr. 1·20, comes into contact with the paste inside the electrodes through a number of holes, in the latter, of 3^{mm} diameter. A layer of Rowland's Universal wax* pasted on to the cork keeps the acid from creeping out. The electrodes can be made more easily of sheet metal by cutting in the form shown in fig. 3, then rolling it into a cylinder. In case it is desired to make a great number of these cells, a die may be made by which sheet metal can be punched out into the desired shape.

These cells have a capacity of about one ampere-hour and give a potential difference of a little over two volts. They keep this potential difference for several months without recharging.

I wish to express my thanks to Professors C. S. Hastings and H. A. Bumstead for their kind interest in and valuable suggestions on this work.

Sheffield Scientific School of Yale University,
March, 1905.

* Ames and Bliss, A Manual of Experiments in Physics, p. 496.

Art. XXXI.—*Chrysoberyl from Canada;* by Nevil Norton Evans.

The mineral chrysoberyl is not one of very limited occurrence, but as yet it has not been reported from any Canadian locality, although rocks apparently similar to those in which it is found elsewhere occur over large areas in Canada. When therefore this mineral was identified in a rock from the Province of Quebec, it was thought well to analyse and describe it, so that the species from this locality might be compared with the same species from other places. The facts concerning its occurrence have been kindly supplied by Dr. F. D. Adams of McGill University, who collected the specimens.

The locality where the chrysoberyl was found is situated in the County of Maskinonge in the Province of Quebec, about 100 miles in a northerly direction from Montreal. It is thus beyond the limit of the settled country and in the woods, in a district which has not as yet been surveyed into townships. The spot is situated on the Rivière du Poste, a tributary of the River Matawin; this river in its turn is a tributary of the St. Maurice River, which runs into the St. Lawrence at the town of Three Rivers. It is about one mile below the forks of the Rivière du Poste, where the streams from Lac Long and Lac Clair run together, and is thus about thirteen miles in a straight line north of the point where the Rivière du Poste

joins the Matawin. This whole region forms part of the great Laurentian peneplain and is underlain by Laurentian gneisses which, in this district, hold in places a few small bands of crystalline limestones. At the locality where the chrysoberyl occurs, the country rock consists of a series of quartzose gneisses; these present a considerable variation in character, being often highly garnetiferous, and they are associated with bands of quartzites. The whole series strikes N. 40–45° W. and has a high east dip. The gneiss, where the river crosses it here, is cut by great veins and dikes of pegmatite; these are composed of quartz, orthoclase and a white mica, with black tourmaline and the chrysoberyl as accessory constituents. The pegmatite, as is not uncommonly the case with this rock, often shows a rapid variation in size of grain from place to place. The chrysoberyl is not abundant, but occurs in well-defined crystals.

The rock specimen brought to Montreal contained two individuals of the chrysoberyl; careful chipping brought out the larger in two fragments and some small chips. The two principal fragments were fitted together and weighed 55 grams. This individual, about half of which is uninjured, has almost exactly the form of a hexagonal prism, apparently quite similar to the one figured in Dana's System of Mineralogy, 1885, fig. 155, terminated at each end by a hexagonal pyramid and end face; it measures an inch and a half across and an inch and a quarter in the direction of the pseudo principal axis; the faces of the pseudo-prism, three of which are almost perfect, give an angle of 120° with the contact goniometer (they are not sufficiently smooth for more accurate measurement), and a seam, running vertically through the middles of two opposite prism faces, two of the pyramid faces, and the end faces, seems to be a plane along which the crystal has at one time been fractured, one-half having been slid along about 1/25 inch from its original position; there is, however, no sign of diminished coherence along this plane now. The material of the crystal is apparently fairly pure except for thin films of iron oxide running through it, and some orthoclase which penetrates it on one side.

The cleanest of the chips were chosen for analysis and were ground to a very fine powder in a specially hardened steel mortar; the powder was subsequently boiled with hydrochloric acid, filtered, washed and dried, to free it from the very considerable quantity of steel abraded from the mortar. The method of analysis employed was a slight modification of that given by Penfield and Harper in this Journal (3), xxxii, p. 114 (1886). After several preliminary trials, two analyses were made of the mineral, in each of which about 0·15 grams of the

powder was fused in a platinum crucible for several hours with a large quantity of potassium disulphate, the fusion was extracted with dilute sulphuric acid, and the insoluble material, apparently silica, was filtered out and weighed. It amounted to a few tenths of a per cent and was deducted from the weight of mineral originally dissolved, the percentage of the other constituents being calculated to the remainder. The iron, alumina and beryllia were then precipitated with ammonia, the precipitate washed and redissolved in hydrochloric acid, the solution being then evaporated in a porcelain dish until crystallization just commenced. To this an excess of a strong solution of sodium hydrate, prepared from the metal in platinum, was added; the porcelain dish was used here, as several experiments showed that platinum dishes were attacked to a considerable extent. The mixture was diluted somewhat with cold water, and filtered; the precipitate was redissolved in hydrochloric acid and subjected to the same treatment as before, the filtrate obtained being added to that previously obtained. The precipitate was redissolved, reprecipitated with ammonia and treated in the usual way, giving the iron. The combined filtrates from the two precipitations by sodium hydrate were poured into a liter of boiling water, the boiling continued one hour, and the perfectly white beryllia filtered out, washed, ignited and weighed. The filtrate from the beryllia was boiled again for a short time to make sure that the precipitation of beryllia was complete, was then slightly acidified with hydrochloric acid, evaporated to a small bulk, and the alumina precipitated with ammonia and determined in the usual way. Tests were applied for calcium and magnesium, but neither was found.

The two analyses agreed very closely and the mean was as follows:

BeO	17·78%
Al_2O_3	76·76
Fe_2O_3	6·07
	100·61

The specific gravity of the mineral was 3·52.

The iron was all calculated as ferric, and this probably accounts in part for the results being high, but no method could be devised for determining the ferrous iron present. No doubt also small quantities of material were dissolved from the dishes and beakers used; their use, however, seemed unavoidable, as platinum was attacked to such a marked extent.

Macdonald Chemical Department,
McGill University, Montreal.

ART. XXXII.—*Souesite, a native iron-nickel alloy occurring in the auriferous gravels of the Fraser, province of British Columbia, Canada;* by G. CHR. HOFFMANN, of the Geological Survey of Canada.

[Communicated by permission of the Acting Director, Dr. R. Bell.]

IN washing the material obtained in dredging for gold in the Fraser river, two miles below Lillooet, Lillooet district, in the province of British Columbia, it has been found that there remains, at the time of cleaning up, a fine, heavy, greyish sand, having a metallic aspect. A sample of this sand, which was sent to the writer for identification, has been examined and found to consist, essentially, of an aggregation of small, very irregular-shaped, rounded grains of an iron-nickel alloy and small to minute, flattened, rounded, steel-grey, glistening scales of native platinum; intermingled with which were some minute, bright, steel-grey colored, irregular-shaped, flattened grains of iridosmine, a few flattened grains of native gold, some minute, partially rounded, crystals of magnetite, a few equally small grains of ilmenite, and a few particles of quartz and of garnet. Of the foregoing, the grains of the iron-nickel alloy constituted, approximately, forty-seven per cent, and those of the native platinum forty-three per cent, by weight, of the whole; the grains of iridosmine, native gold, magnetite, ilmenite, and of quartz and garnet, making up the balance of ten per cent.

This iron-nickel alloy occurs, as above described, in the form of small, very irregular-shaped, rounded grains, the largest not exceeding a millimeter and a half in diameter, whilst many, indeed the greater number, were of far smaller dimensions, and others were of microscopic minuteness. It has a faint yellowish steel-grey color, and a submetallic lustre; is strongly magnetic, and malleable. Its specific gravity, at 15·5° C., is 8·215. The mineral is but very slightly acted upon by hydrochloric acid in the cold; upon the application of heat, however, it very slowly passes into solution. It is readily attacked by dilute nitric acid, even in the cold, and is easily and completely dissolved by it on heating.

The mean of two very closely concordant analyses, conducted by Mr. F. G. Wait, upon very carefully selected material, showed it to have the following composition:—

Nickel	75·50
Cobalt	none.
Iron	22·02
Copper	1·20
Insoluble siliceous matter	1·16
	99·88

Deducting the insoluble siliceous matter, and recalculating the remaining constituents for one hundred parts, we obtain, as representing the composition of the mineral:—

Nickel	76·48
Iron	22·30
Copper	1·22
	100·00

There are only two instances on record of a mineral similar to that above described having been met with. One of these being the nickeliferous iron called "awaruite," referred to by W. Skey (Trans. N. Zeal. Inst., vol. 18, p. 401, 1885) as having been found, associated with gold, platinum, cassiterite, chromite, and magnetite, in the drift of the Gorge river, a stream flowing into Awarua Bay, on the west coast of the South Island of New Zealand; and the other, the iron-nickel alloy described by A. Sella (Compt. Rend., vol. 112, p. 171, 1891) as occurring in the auriferous sands of the Elvo, a mountain-stream, near Biella, Piedmont, Italy.

As tending to facilitate a comparison of these three, apparently closely related, minerals with each other, their analyses are here given in a tabular form,—(1) being the analysis of the nickeliferous iron "awaruite"; (2) that of the iron-nickel alloy from the Elvo, Piedmont; and (3) the analysis, after deducting some insoluble siliceous matter and recalculating the remaining constituents for one hundred parts, of the iron-nickel alloy from the Fraser river, province of British Columbia.

	G	Fe	Ni	Co	Cu	S	SiO_2		
(1)	8·1	31·02	67·63	0·70	..	0·22	0·43	=	100·0
(2)	7·8	26·60	75·20*		..	..	..	=	101·8
(3)	8·215	22·30	76·48	..	1·22	..	..	=	100·0

The writer would suggest that this mineral be named "souesite," after Mr. F. Soues—to whom he is indebted for the sample sent for identification—to distinguish this find from that of other naturally occurring iron-nickel alloys.

*Nickel, with some cobalt.

Art. XXXIII.—*On the Absence of Helium from Carnotite;* by E. P. Adams.

The experiments of Sir William Ramsay and Soddy on the formation of helium from the radium emanation account very readily for the well-known fact that the minerals which contain helium in appreciable quantity contain as well one or more of the radio-active elements. It might therefore be expected that all radio-active minerals should contain helium.

I have recently been testing various specimens of carnotite to determine whether or not helium is present in them. Carnotite promises to become an important source of radium; certain specimens have been found which have a radio-activity 1·6 times that of metallic uranium, although it appears to be difficult to obtain large quantities of mineral of such high activity. On heating in vacuo several grams of this carnotite, considerable quantities of carbon dioxide and water were driven off, and when these were absorbed by caustic potash and phosphorus pentoxide respectively, only the nitrogen spectrum could be observed when an electric discharge was sent through a vacuum tube connected to the pump; no difficulty was found in obtaining the helium spectrum when only a tenth as much pitchblende, monazite sand, or thorianite* was used.

The quantity of gas which was obtained from this amount of carnotite was so small that it was thought worth while to work with a larger quantity of the mineral. For this purpose, 300 grams of carnotite of activity 0·8 times metallic uranium was heated at a red heat in vacuo for three hours, and after absorbing the carbon dioxide by caustic potash, about 10^{cc} of a gas remained. On sparking this, after adding oxygen, in order to absorb the nitrogen present, a rapid decrease in volume took place, and when finally the excess of oxygen was absorbed by means of phosphorus, only about $0{\cdot}1^{cc}$ of a gas remained. This when introduced into a spectrum tube showed the characteristic red spectrum of argon. It was observed that the greater part of the gas, aside from the carbon dioxide, was given off on the first gentle heating, and it is therefore probable that the argon was associated with the air held in the powdered mineral, which was completely driven off only on heating it.

It therefore appears that if helium is contained in carnotite at all, it exists in far smaller amount than would be expected from the quantity of radium present. But it is probable that

* The recently discovered mineral from Ceylon, containing about 75 per cent of thorium, kindly supplied by Dr. George F. Kunz for this purpose.

this absence of helium may be explained by the physical properties of the mineral. Carnotite is a very fine powder which is usually found disseminated through sandstone. Now even the most compact specimens of this sandstone containing carnotite are exceedingly permeable to gases. This was shown by closing one end of a glass tube with a piece of the mineral about 2^{cm} in thickness, and filling it with illuminating gas over water. In a few minutes the water rose a distance of $6–7^{cm}$ in the tube. If we then assume helium to be formed in this mineral by the disintegration of the radium, it appears reasonable to suppose that it rapidly diffuses away. The minerals that contain helium are known to be massive, impervious substances, which are therefore able to retain the helium formed in them.

This explanation of the absence of helium from carnotite seems to be supported by the views of Travers* on the state in which helium exists in minerals. According to him, the helium is present in the minerals in a state of supersaturated solid solution; the minerals being impermeable to the gas at ordinary temperatures, the velocity with which equilibrium is established between the helium in solution and the helium in the gaseous phase is very small, but increases rapidly with rise of temperature. In the case of carnotite, however, the mineral is permeable to the gas even at ordinary temperatures, and therefore we could not expect to find any appreciable amount of helium in this mineral.

Princeton University, Physical Laboratory.

*Nature, Jan. 12, 1905.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Properties of Methane.*—In preparing pure "marsh gas," Moissan has made use of crystallized aluminium carbide made by heating aluminium with carbon in the electric furnace, then dissolving the excess of aluminium by treatment with hydrochloric acid at 0°, washing with ice-water, dry alcohol and ether, and drying in a vacuum. The aluminium carbide, thus purified, was allowed to act upon water at ordinary temperature in order to produce the methane gas. The gas was then liquefied and solidified, and from the solid product pure gas was obtained for experimental purposes. Eudiometric analysis, by explosion with oxygen, and subsequent absorption of carbon dioxide, gave results agreeing very closely with theory. The density, by direct weighing in comparison with air, was found to be ·5540 and ·5554 as the results of two determinations, which agree very closely with the theoretical density, and are a little lower than that previously found by Thomson and by Schlœsing (·558). When methane was brought into a tube surrounded with liquid air, it solidified at first in a transparent form, like glass; but after a few moments it suddenly crystallized in white needles. It was found to melt at −184° and to boil at −164°. It was found that methane always has a mild, slightly alliaceous odor, which cannot be attributed to impurities. Experiments showed that solid methane is attacked by liquid fluorine at −187° with explosive violence, similar to the action of solid fluorine upon liquid hydrogen. This is another case, therefore, where chemical affinity persists at very low temperatures.—*Comptes Rendus*, cxl, 407. H. L. W.

2. *Silicide of Carbon in the Cañon Diablo Meteorite.*—The fact that Moissan has found the substance commonly called carborundum in the residue obtained by dissolving 53 kg. of this meteorite has already been noticed in this Journal. The first announcement of this discovery was perhaps not entirely convincing, as it was based merely upon finding crystals exactly resembling silicide of carbon. Further examination has enabled Moissan to show, after separating the minute crystals by means of a heavy solution, that they possess the physical and chemical properties of the compound, and also that they are composed of silicon and carbon. There is now no doubt, therefore, that this interesting compound, previously known only as a product of the electric furnace, actually occurs in nature.—*Comptes Rendus*, cxl, 405. H. L. W.

3. *A New Process for Detecting Ammonia in Water.*—Trillot and Turchet take 20 or 30^{ccm} of the water to be tested in a test-tube, then add three drops of a ten per cent solution of potassium iodide and two drops of a concentrated solution of an alkaline hypochlorite (commercial Javel's solution). When ammonia is

present, a black coloration is immediately produced, due to the formation of nitrogen iodide. In doubtful cases, where iodine may be set free, a slight excess of the hypochlorite is added in order to dissolve the iodine. The color is sufficiently stable to allow of calorimetric comparison with known amounts of ammonium chloride solution. The authors claim that foreign substances interfere with this reaction less than with Nessler's test, and that other nitrogenous substances do not yield the same reaction.—*Comptes Rendus*, cxl, 374. H. L. W.

4. *Radio-tellurium.*—MARCKWALD has worked up the crude tellurium obtained from about 15 tons of pitchblende. By dissolving the material and precipitating with sulphur dioxide, about 16 g. of a mixture of selenium, tellurium and radio-tellurium were obtained. Upon oxidizing this with nitric acid, evaporating to dryness and warming with solution of ammonia, a residue weighing about 3 mg. was obtained, which apparently contained practically all of the radio-active material, and possessed "enormous" activity. It is Marckwald's opinion that his radio-tellurium is a distinct substance, not identical with polonium.—*Berichte*, xxxviii, 391. H. L. W.

5. *Conversations on Chemistry, Part I, General Chemistry;* by W. OSTWALD. Authorized Translation, by Elizabeth Catherine Ramsay. 12mo, pp. 250. New York, 1905, John Wiley & Sons.—The eminent author was led to write this work, for one reason, on account of the benefit that he derived from using a book of similar character, Stöckhardt's "Schule der Chemie," as his first text-book of chemistry. As another reason, he hopes to overcome the tendency to onesidedness due to the great attention paid to organic chemistry at the present time in Germany, by presenting a treatise on general and physical chemistry, since these may be regarded as the foundation for all real chemical education.

The form of dialogue between master and pupil has been adopted, because it appeared to occupy no more space than ordinary description, while the impression made is much more "penetrating and lively." This is going back to a form of text-book considerably used by our grandparents, but, while we may frequently smile at the almost superhuman aptitude of the pupil in asking the proper questions and in making appropriate comments, the impression gained by an examination of this little book is that it is a most excellent and valuable one.

The book under consideration, which is the first part of a series, deals only with common and simple chemical and physical phenomena. No attempt is made here to introduce any chemical theories, but many points of physics are very clearly explained. The experiments presented are very satisfactory ones. The translator has done good work, and few traces of the German idiom are evident; indeed, there is sometimes doubt in regard to the original language used to express youthful astonishment, as, for example, where the pupil exclaims, "Oh, how ripping," upon observing a striking experiment. H. L. W.

6. *Text-book of Organic Chemistry;* by HENRY LEFFMANN, A.M., M.D. and CHAS. H. LAWALL, Ph.D. Pp. 231. Philadelphia, 1904. (P. Blakiston's Son & Co.)—The work is obviously intended for the use of students of medicine and pharmacy. Throughout the book structural formulas are given, even for such complicated compounds as the purine bodies, cocaine, piperine, camphene, salicin and lecithin. But nowhere is there the slightest suggestion that an accepted structural formula, simple or complicated, is the result of a study of reactions. Asymmetric carbon is referred to and stereochemical formulas printed, but the reason given for the latter is that "as molecules occupy space it is desirable to formulate them on a three-dimensional system." Such treatment is calculated to give an entirely wrong idea of the subject, even though the authors have shown in the main good judgment in selecting the compounds to be treated and have given, usually though not always, the structures commonly accepted by chemists. A student acquires some useful information by studying about the occurrence and physical properties of organic compounds, he learns more by studying those reactions from which are drawn conclusions as to the structure of typical compounds; when he has the elementary knowledge he may even learn something about the behavior of complicated compounds by looking at the accepted structural formulas, but such formulas are confusing and meaningless to one who has not acquired the elementary knowledge. W. J. C.

7. *Electric Inertia.* — Sir Oliver Lodge, in an address before the Institution of Electrical Engineers 1903, calculates the inertia which a small sphere charged with a quantity e of electricity and moving with a velocity u has in virtue of its charge. S. H. BURBURY shows that the magnetic force assumed by Lodge to arise in space from the motion of the sphere is exact if u is supposed to be constant, and also e the charge on the sphere. It is not, however, exact if u or e vary.

Burbury also asks whether it would not be safer to apply other limits of integration than those employed by Lodge. The paper is a keen criticism of the generalities of the theory of electric inertia.—*Phil. Mag.*, Feb., 1905, p. 243–250. J. T.

8. *Double Refractions.* — FERDINAND BRAUN shows various methods by means of which artificial double refraction can be produced. A thin bundle of glass wool threads made into a layer 1^{mm} thick shows changes in light under crossed nicols in a polarization microscope; the phenomena can be controlled by immersing the bundle in various oils. The author describes also a method of making stratified dielectrics, which consists in covering glass plates with collodion films, alternating with films of aloe resin (the collodion films are dipped in the resin). Thirty such plates show the Iceland spar cross, and eighty, the ring. Gelatine plates soaked in water until soft, immersed in methyl-alcohol, and built up in a symmetrical orientation, give beautiful images, such as are produced by biaxial crystals. The

author found that similar preparations had been made by earlier observers, especially Nörremberg, and Bertin. Braun extends their work and shows that one of his preparations $2{\cdot}8^{mm}$ thick gave rings equal to those produced by a plate of apatite half as thick; or a plate of calcite, $0{\cdot}1^{mm}$ thick.—*Ann. der Physik.*, No. 2, 1905, pp. 278–281. J. T.

9. *Emission Spectra of the Metals in an Electric Oven.* — Spectroscopic observations conducted with the electric arc and spark are conditioned to a great degree by electrical phenomena which are difficult to isolate from the mere effect of heat. A. S. King has developed an electric oven similar to one used by Liveing and Dewar, in order to excite emission spectra only through heat. The forms of oven are described at length. The vapors of the metals emitting spectra are formed close to the hot carbon electrodes in these ovens. A resistance oven is also described in which the heat developed by the white-hot resistance excites the emission spectra. Many interesting results were obtained which are summed up as follows:

1. The oven affords emission spectra which in intensity differ widely from those obtained in the electric arc.

2. The method is especially suited for the observation of band spectra.

3. The changes in the series spectra of caesium show that the glowing vapor follows the radiation law of solid bodies.

4. Comparison of series lines in arc and spark spectra of different elements shows that changed electrical conditions can work in the same way as changed temperature conditions.

5. The calcium spectrum in the oven shows a particular relationship of the lines H and K which appear weakly only at the highest temperature. The *g*-line shows an unsymmetrical broadening of the reversal so that it appears to be displaced. The vapor of the oven shows a much greater absorption power for *g* than for the other lines of the spectrum; this line varies with the temperature.

6. The homologous pairs in the spectrum of Ca, Sr, Ba, with like magnetic types, are relatively much weaker in the oven than in the arc.

7. The oven spectrum gives new bands in the spectra of Ca, Sr, Ba, and Cu. In the green-band group of Ba, there is an apparent displacement of the position of maximum intensity from band to band.

8. The relative intensities of the Cu-lines of the oven approximate to those in a weak arc; the absence of ultra-violet pairs indicates temperature as the source of the radiation.

9. In many cases only a trace of a substance is sufficient to evoke characteristic lines.

10. It is shown that ionized steam, which arises from the arc but is separated from it, gives the arc spectrum even when it lies outside the path of the current.

11. Water vapor in the oven heightens the intensity of metal lines.—*Ann. der Physik*, No. 2, pp. 360, 381. J. T.

10. *The Dynamics of Particles and of Rigid, Elastic, and Fluid Bodies;* by A. G. WEBSTER. Pp. xii+588. Leipzig, 1904. (B. G. Teubner.)—This book is a welcome addition to the long list of text-books on mechanics. The gap between the elementary treatises and the classics of the science is wide and difficult to fill. The mere extent of the field to be covered makes the tasks of compression and selection as important as they are difficult. And at the same time the voluminous literature in each separate department makes a single-volume introductory work giving adequate treatment of the methods (necessarily at the expense of many of the applications) very highly desirable. It is this task that Professor Webster has set himself, and, in the opinion of the writer, very successfully performed.

The field covered is sufficiently indicated in the title. Kinematics is not treated as a separate subject, but is taken up as introductory to each subdivision of dynamics in order. The chapters on the general principles and methods of advanced dynamics are especially to be commended. Students of physics are too often insufficiently acquainted with such matters as generalized coordinates, the calculus of variations, Hamilton's principle, etc.; or if at all it is an academic and not a working knowledge which they possess. For all such the above-mentioned chapters should furnish a valuable guide. The section on rigid dynamics might possibly be criticized as being disproportionately full in the treatment of gyroscopic motion: a fault, if it be a fault, both to be expected and condoned in an author whose original contributions to this subject are so well known. The general theory of the potential function forms the introduction to the section on the dynamics of deformable bodies. This chapter follows very closely the presentation of the same subject in the author's well-known "Theory of Electricity and Magnetism." The remaining chapters of this section,—those on elasticity and hydrodynamics,—are, relatively to their importance, the shortest in the book. They form, however, an excellent introduction to the very extensive literature of these topics.

Typographically and in the matter of illustrations the book is unusually excellent. It appears as the eleventh in the Teubner collection of text-books of the mathematical sciences. L. P. W.

11. *Experimentelle Untersuchung von Gasen;* by M. W. TRAVERS. German translation by T. ESTREICHER. Pp. xii+372. Braunschweig, 1904 (Friedrich Vieweg und Sohn).—This German edition of Professor Travers' invaluable "Experimental Study of Gases" is not a mere translation, but presents considerable matter that is not contained in the English edition of 1902, in addition to being largely rewritten. The book is so well known that it is only necessary here to point out some of the additions which appear in this edition. The chapters on the liquefaction

of gases and on the handling of the same contains much new matter, especially with reference to the liquefaction of hydrogen and the fractional distillation of gas mixtures at low temperatures. All the very recent determinations of the physical constants of the rare gases of the argon group, as well as the new methods used in their measurement, are included. An entire new chapter has been added by the translator on the specific and latent heats of gases, which contains much valuable information both as to methods and results. These constitute the main additions.

As a whole, this German edition can be said to add to the value of a work already indispensable to the worker in gas analysis or low temperature research. L. P. W.

12. *The Dynamical Theory of Gases;* by J. H. JEANS. Pp. viii, 352. Cambridge, 1904. (University Press.)—In the first five chapters of this book is given the theory of the distribution of velocities and of the partition of energy in conservative systems. Two methods of deriving the law of distribution of velocities are given: the classical method of Maxwell and Boltzmann, and a method devised by the author which is not unlike that of Gibbs (Elementary Principles in Statistical Mechanics). Then follow two chapters developing the physical properties of gases as predicated by this theory and the comparisons with experiment. The unsatisfactory result of this comparison, especially in the case of the ratio of the specific heats, is due to the fact that the theory assumes that molecules form conservative systems. This leads to the theory of a non-conservative gas which is treated in the next three chapters. Here for the first time in the book is introduced an hypothesis as to the structure of the molecule. The assumption is made (supported by the evidence of spectroscopy) that the ultimate components of the gas possess a number of isochronous free vibrations. With the aid of this assumption the complete theory is worked out, and the agreement with experiment is shown to be of a very satisfactory nature. Next come six chapters on the various free path phenomena. The book concludes with applications of the theory to planetary atmospheres, molecular aggregation and dissociation, and the calculation of the size of molecules. In the appendices are given tables to aid in the evaluation of the exponential integrals of common occurrence in the kinetic theory.

Altogether this is the most satisfactory treatise on the subject that the writer knows. It is particularly excellent in its treatment of the historic difficulties connected with the question of the partition of energy. The treatment of the non-conservative gas is very original and suggestive. The orderly perspicuous development, the excellent historical perspective, the clear separation of assumption and fact, and the unusual attention paid to the quantitative numerical side of the subject, all contribute to make this one of the notable books of the year. L. P. W.

13. *Optical Pyrometry.*—A paper by C. W. WAIDNER and G. K. BURGESS in the second number of the Bulletin of the Bureau of Standards (see also p. 91, Jan., 1905) gives a thorough discussion of the subject of optical photometry, both as regards theory and methods. The experimental comparison of the various types of optical pyrometers is particularly thorough and valuable. The authors conclude, on the basis of their experiments, that the several laws of radiation are in quite satisfactory agreement at the highest attainable temperatures and thus serve to define the same scale of temperatures. For example, they state that "it would seem that the radiation laws are still in agreement at the temperature of the arc. Our measurements have given as the black body temperature of the hottest part of the positive crater 3690°, 3680°, and 3720° absolute, as determined with the Holborn-Kurlbaum, Wanner, and Le Chatelier pyrometers, based on the extrapolation of Wien's law. Féry gets for this temperature 3760° by a method based on Stefan's law."

II. GEOLOGY AND MINERALOGY.

1. *Cambrian Brachiopoda with Descriptions of New Genera and Species;* by CHARLES D. WALCOTT. Proc. U. S. National Museum, xxviii, 1905, pp. 227–337.—This is the sixth paper of the preliminary studies for the monograph on the Cambrian Brachiopoda, to be published by the U. S. Geological Survey. In it are described 106 new species, 50 old species, 8 old genera, and the following new genera or subgenera: *Otusia* (type *Orthis sandbergi* Winchell), *Nisusia* (type *Orthis festinata* Billings), *Jamesella* (type *Orthis perpasta* Pompeckj), *Eostrophomena* (type *E. elegantula* new), *Orusia* (type *Orthis lenticularis* Wahlenberg), *Finkelnburgia* (type *F. finkelnburgi* new), *Loperia* (type *L. dougaldensis* new), *Swantonia* (type *Camarella antiquata* Billings), *Rustella* (type *R. edsoni* new), *Curticia* (type *C. elegantula* new), *Quebecia* (type *Obolella circe* Billings), and *Schuchertina* (type *S. cambria* new).

As the generic name *Iphidea* Billings, 1872, was preoccupied by Boyle, 1865, Dr. Walcott here changes the name to *Iphidella.* However, as two other generic names have been proposed for species referred by Walcott to *Iphidella* we are obliged under the rules of nomenclature to replace his by one of these names. The earliest one is Meek's *Micromitra* (type *Iphidea* (?) *sculptilis*), or Beecher's *Paterina* (type *Obolus labradorica*). As *I. sculptilis* has an ornamental surface, it may be well to retain *Micromitra* in a subgeneric sense, in which case we are forced to adopt *Paterina* for the unadorned forms to replace the preoccupied name *Iphidea* Billings.

From the six papers thus far issued, it is evident that Dr. Walcott's monograph is not only to be a monumental volume, but that students of brachiopods will have a firm foundation on which

phylogenies and a final classification of these organisms can be built. C. S.

2. *Occurrence of Mastodon humboldtii in Northern Mexico.*—A small collection of Mastodon material, from near the line of the Chihuahua al Pacifico R. R., was presented to the Yale University Museum in 1902, by Mr. CHARLES SHELDON (Yale 1890). The remains include part of an upper tusk and fragments of a tooth from Guerrero, near Concepcion, in the state of Chihuahua, Mexico; also the head of a femur, which was found about sixty miles from Chihuahua. The tooth may be identified with the third upper molar of *Mastodon humboldtii* Cuv., as the cross-crests show the peculiar "double-trefoil" pattern characteristic of that species, and otherwise agree closely with Prof. Cope's definition of *Mastodon* (=*Dibelodon*) *humboldtii* (Fourth Annual Report, Geol. Surv. Texas). This identification is of considerable interest, inasmuch as Prof. Cope stated (*loc. cit.*) that the supposed occurrence of the species in Mexico was based on a misapprehension, the specimen from Mexico described as *M. humboldtii* by Von Meyer (Palaeontographica, 1867) being subsequently arranged by Cope under the new species *Dibelodon tropicus*.

G. F. EATON.

3. *Petrography and Geology of the Igneous Rocks of the Highwood Mts., Montana;* by L. V. PIRSSON. Bull. 237, U. S. Geol. Surv., 1905, 208 pp., 7 pls.—The Highwood Mountains form a group of much eroded volcanoes situated on the great plains of Montana within the great bend on the Missouri River. They present stocks of granular rocks filling the old conduits, which are surrounded by a vast network of radial dikes. There are some intruded sheets and masses of extrusive flows, breccias and tuffs, remnants of the former cones. On the southeast there is an interesting region of intruded laccoliths which affords examples of rock differentiation in place.

The igneous rocks composing these varied masses are of alkalic types, mostly basic in character with a prevailing dominance of potash in the alkalies. They afford a number of interesting and novel kinds, some of which, such as shonkinite and missourite, have been previously described by the author in conjunction with Mr. W. H. WEED. In this bulletin the geology of all these occurrences is described and the petrography of the different rocks given in full detail with chemical analyses. The new quantitative system of classification is used, giving an opportunity of testing its practical working. In conclusion, the bearing of the facts observed on the origin and differentiation of igneous rocks is treated.

4. *Red Beryl from Utah;* by W. F. HILLEBRAND. (Communicated.)—From Mr. Maynard Bixby of Salt Lake City, there have recently been received three crystals of beryl which because of their color—a rich raspberry-red—seem to merit notice. The specimens show single crystals of short prismatic or tabular shape, 3 millimeters in height and up to 7 millimeters across the basal plane, implanted on imperfect topaz crystals. According to Mr. W. T. Schaller, the only other forms are those of prisms of

the first and second order, the habit being the usual one for beryl, and the specific gravity is 2·65. The color is presumably due to manganese, of which the crystals contain a very appreciable amount. Approximate chemical determinations leave no doubt as to the identity of the species. The locality of occurrence is that make known by the discovery of bixbyite, about 35 miles southwest from Simpson Springs, Utah, in the Dugway Range. The matrix is rhyolite, and the chief associates, according to Mr. Bixby, are topaz, bixbyite and altered garnets.

5. *The Nickel and Copper Deposits of the Sudbury Mining District, Ontario, Canada;* by ALFRED ERNEST BARLOW. 236 pp., with 24 plates and five geological maps. From vol. xiv of the Annual Report of the Geological Survey of Canada. Part H.—The importance of the Sudbury mines will be appreciated when it is stated that they now give Canada the position of the largest producer of nickel in the world. This report by Mr. Barlow is an admirable presentation of the whole subject, describing the geological relations and composition of the deposits, discussing their origin and also giving an account of the methods of mining and metallurgical processes. A summary is also added of the occurrence of nickel in other parts of the world, with particular reference to the Scandinavian deposits which in many respects are strikingly similar to those of Canada.

The nickel- and copper-bearing ore bodies consist essentially of pyrrhotite, by far the predominant constituent, chalcopyrite in much smaller amount and also pyrite. The nickel, however, is almost entirely confined to the species pentlandite, which is in general very uniformly distributed throughout the whole mass. Both the pyrrhotite and pyrite carry nickel in small amount, but it is not certain that it really belongs to the composition of these minerals, some authorities referring it here also to admixed pentlandite. Besides the species mentioned, the following nickel minerals also occur in limited amount: millerite, polydymite, niccolite, gersdorffite and marcasite. Other associated species are the following: morenosite, annabergite, sperrylite, danaite, smaltite, galena, chalcocite, bornite, magnetite, cassiterite, native copper, native gold, graphite, cubanite and some others.

The deposits occur in connection with certain eruptive rocks. These are discussed by the author under two divisions:

(1) A basic portion:—Including certain gabbroid rocks, chiefly, at least, of the norite facies, with their derivative diorites, with which the nickel- and copper-bearing sulphides are immediately associated.

(2) An acidic portion:—Comprising large areas of rock of granitic type, with well-marked gneissoid structure, the prevalence and abundance of the graphic intergrowth of the quartz and feldspar, known as granophyre or micropegmatite, having suggested the name "micropegmatite," by which this rock is now generally known.

The origin of the ore deposits is discussed in detail and the author states his belief that the Sudbury deposits, like those of

Norway described by Vogt, are of igneous origin, being the direct product of the differentiation of a basic igneous magma modified to some extent by certain secondary processes.

III. Miscellaneous Scientific Intelligence.

1. *Studies in General Physiology;* by Jacques Loeb. The Decennial Publications of the University of Chicago, 2 vols., 782 pp. University of Chicago Press, 1905.—These studies include a series of papers collected from Professor Loeb's important contributions to general physiology during the past fifteen years. The range of topics selected is broad; yet, in the words of the author, "a single leading idea permeates all the papers of this collection, namely, that it is possible to get the life-phenomena under our control, and that such control and nothing else is the aim of biology." The present form of presentation will be especially welcome to many readers, since most of the papers are here given in English translation for the first time. In this collection will be found the well-known researches of Loeb on the heliotropism of animals and on heteromorphosis, various papers in the field of physiological morphology—the study of the connection between chemical changes and the process of organization in living matter; while most of one volume is devoted to investigations involving the application of the modern physical chemistry to the solution of biological problems. Prominent among these are studies on the physiological rôle of ions, and the splendid observations on artificial parthenogenesis. The reader may, at times, be inclined to hesitate in accepting the generalizations of the author; but one must admire the enthusiasm and untiring energy of the investigator, the wealth of important observations presented, and the originality of treatment which fundamental problems receive. Professor Loeb has won an enviable reputation which is well deserved. The University of Chicago is to be congratulated in the publication of these commemorative volumes. L. B. M.

2. *The Birds of North and Middle America;* by Robert Ridgway. Part III, pp. xx, 801 with 19 plates. Bulletin No. 50 of the U. S. National Museum.—This is the third part of this important work, already noticed in these pages; it includes the species of fifteen families from the Wagtails and Pipits (Motacillidæ) to the Warblers (Sylviidæ). The three volumes already published include some twelve hundred and fifty species and subspecies, that is about two-fifths of all the North and Middle American Birds.

3. *British Museum Catalogue:—A Synonymic Catalogue of Orthoptera;* by W. F. Kirby. Vol. I, pp. x, 501. London, 1904.—The author, who has recently carried through a re-arrangement of the Orthoptera of the British Museum, has now prepared a complete catalogue of the Order. This first volume contains the species of five families and the remaining three will be included in one, or possibly two, additional volumes. This work will be of great value to all students of Entomology.

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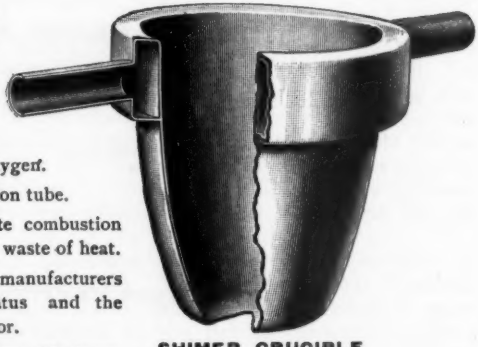

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